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THE LIMITATIONS FOR NIGHT-TIME DETECTION OF CELESTIAL BODIES EMPLOYING THE INTENSIFIER-STORAGE-IMAGE ORTHICON

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INTRODUCTION

The purpose of this paper is to calculate the results one may expect by using the image orthicon and intensifier image orthicon for detection of celestial bodies during night time hours. The paper treats, in Part I, the image orthicon without intensifiers and calculates the limit in detection determined by the scanning beam noise. In the Part II, the preamplification necessary for the intensifier section to overcome this scanning beam noise is calculated. The intensifier image orthicon is not necessarily the only arrangement for overcoming this beam noise. Intensifier image converter tubes effectively placed between the telescope and an image orthicon could produce the same results; however, such a solution is not suitable for use in flight vehicles because it results in a heavy bulky arrangement.

PART I

Image Orthicon without Intensifiers with Negligible Noise due to Sky Radiation and Dark Current Emission of the Photocathode

In deriving the following equations, it has been taken into consideration that the mechanisms of the operation of the image orthicon are of a complex nature, and not too easily understood. Therefore, to render the mathematical derivations simple and clear, factors of minor importance were deliberately neglected and the relationships were expressed by the most elementary functions.

The image orthicon, well-known from television techniques, constitutes one of the most suitable tools for light amplification. It is the most advanced workable pickup device for short exposure time star photography, but may be superseded by another transducer now in the development stage, the new image isocon.* For proper understanding of this paper a superficial familiarity with the image orthicon's structural and operational features is necessary. The image orthicon consists of several sections: the image section, storage section, scanning section, and multiplier section (fig. 1). First, the image of the scene is projected by a telescope onto the photocathode of the image section which emits primary electrons as a result of the absorbed energy of the quanta of light (hereafter called simply "photons"), thus changing the optical image into an electronic one. The primary electrons are magnetically focused and accellerated by an electrostatic field and hit the target plate of the storage section, where each primary electron causes the emission of S secondary electrons, producing S positive charges. One of these unit charges is neutralized by the primary electron; the rest, (S–1) unit charges, are "stored" as a positive charge on the target plate, forming an amplified electronic image of the scene.

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The next operation is the removal and "count" of the integrated stored positive charges by a beam of electrons scanning the target plate and being reflected backwards. The reflected or "return" beam contains a lesser number of electrons, than the scanning beam, since some of the electrons land on the target plate corresponding to the charge pattern in order to neutralize the charge. The difference in the number of electrons contained in the scanning and return beams is practically equal to the integrated number of charge units stored on the target between two consecutive sweepings with the scanning beam. This is true independently of the time elapsed between the subsequent sweepings, if allowance is made for the loss of charge units due to a slow, but unavoidable, leakage. As a result of this leakage, and other factors, the image produced by such a sensor has a limited resolution and, therefore, may be considered composed of small defined elements of resolution. Other factors contributing to loss of resolution are: the light focused on and absorbed by the photocathode contains a distribution in wavelength causing a distribution of velocity in the electrons released, insufficient electron-optics, finite diameter of the scanning beam, and finite band-width of the video amplifying system. However, at very low light levels, because of the quantum nature of light, the smallest area such an instrumentation is capable of resolving may not collect a detectable number of photons and, therefore, may

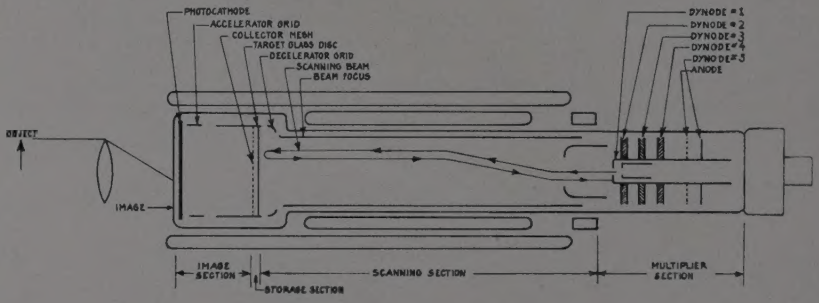

FIGURE 1. Conventional image orthicon.

have to be increased in order that, for the unit of time available, a sufficient number of quanta of light for detection are received. The conversion factor of photons into electrons of a photocathode is independent of the local density of the quanta flux; and since storage of the collected charges at the target plate over an arbitrary unit of time integration can be achieved, the function of such a device depends on the total number of photoelectrons released at the photocathode for each resolution element during the exposure time, rather than on the local density of the quanta flux. However, in the photographic plate and similar processes if the local density of the quanta flux is very low, then the failure of the photographic reciprocity law requires that the flux density also be considered.

Therefore, in the derivations to follow, if not otherwise stated, the term "total number" of photons or electrons means that number within each element of resolution which have occurred during the selected time interval.

If the detection of fast moving celestial objects is achieved by using an image orthicon system, the read-out of information from the target plate can be done by scanning the target plate in the conventional manner, by using a continuous frame rate of 20 to 60 frames per sec. In addition to using a continuous frame rate, the first photocathode may also have to be pulsed, if the object moves very rapidly, or if movement of the image due to air scintillations has to be stopped,

because conventional sweep rates might not be fast enough to stop the motion. This would apply only to objects bright enough to supply sufficient quanta of light for detection during the short exposure time. However, for the observation and recording of faint, non- or slow-moving celestial bodies, the exposure time may have to be extended to such a time interval that continuous read-out becomes impractical. For this type of arrangement, the scanning beam is not operating during the exposure time, thereby allowing the target plate to collect a sufficient charge that can be detected later by the scanning beam. After completion of the exposure time, this information is then removed from the target plate and transferred to the reproducer screen by one single sweep of the scanning beam. The correct time duration of the read-out sweep is determined by the band-width of the video amplifier and other circuitry factors. Since the information read-out is not continuous, and one single frame with a time duration of a fraction of a second is used which cannot be visually observed on a conventional reproducer, it is quite convenient to use a storage reproducer in connection with such an image orthicon system. The resulting visual observations on the storage reproducer which can be over several minutes then allow the determination of the optimum adjustments for photographic recording.

Beginning with the operation of the target section of an image orthicon, we compute the number, e_t, of positive unit charges owing to the star radiation, stored on the target plate in any one element of resolution. The number e_t is, evidently, equal to the number of the photons, Q_s, arriving from the star onto any equivalent resolution element of the photocathode, multiplied by the photon to electron conversion yield of the photocathode, η_P, which is usually called the quantum efficiency of the photocathode, and the effective secondary emission yield multiple (S–1) of the target. (*See appendix, p. 145, for symbols.*)

$$e_t = Q_s \cdot \eta_P (S-1) \tag{1a}$$

And since $Q_s \cdot \eta_P$ is the number of electrons, e_s, emitted from the photocathode owing to the star radiation in any one element of resolution during the chosen unit of time

$$e_t = e_s (S-1). \tag{1b}$$

Now, Q_s is equal to the photon flux, Q_M, to which the lens area, $D^2\frac{\pi}{4}$, is exposed and which is concentrated upon the image area, $D_i{}^2\frac{\pi}{4}$, multiplied by the lens transmission coefficient, η_T, the area of a resolution element, $D_r{}^2\frac{\pi}{4}$, and the exposure time, t_e. Thus, the number of photons collected by each resolution element in the focal plane in the time t_e; i.e.,

$$Q_s = Q_M \cdot D^2 \frac{\pi}{4} \eta_T \frac{D_r{}^2 \frac{\pi}{4}}{D_i{}^2 \frac{\pi}{4}} \cdot t_e. \tag{2a}$$

However, this equation is valid only if D_r is substantially smaller than the image diameter, D_i. If the resolution element were substantially larger than the star image, all of the photons collected by the photocathode would land inside the resolution element, and the equation would read:

$$Q_s = Q_M \cdot \eta_T \cdot D^2 \frac{\pi}{4}. \tag{2b}$$

To obtain an expression for Q_s, covering the entire range, we set,

$$Q_s = Q_M \cdot \eta_T \cdot t_e \cdot D^2 \frac{\pi}{4} \cdot \frac{1}{K} \tag{3}$$

where the "coverage factor," K, is included between 1 (unity) and

$$K = \frac{D_i^2}{D_r^2} \geqq 1 \tag{4}$$

the value of K for $D_r \approx D_i$ depends on the focal length of the employed optical system, effective angular resolution, angular size of the celestial body in case it

is a planet, etc., scintillations of the star image during the exposure time, and haze, as well as design limitation of the sensor. However, this equation is of particular practical interest, e.g., for matching the optical resolution of a telescope with the resolution of the sensor.

The number of positive charges stored on the target becomes, according to Eqs. (1) and (2)

$$e_t = Q_s \cdot \eta_P \cdot (S-1) = e_s(S-1) = Q_M \cdot D^2 \frac{\pi}{4} \eta_T \cdot \eta_P \frac{t_e}{K} (S-1) \tag{5}$$

where

$$Q_M = Q_o \cdot 2.512^{-M}, \tag{6}$$

and Q_o is the number of photons received on the telescope lens per unit area and time from a star of apparent magnitude number M = zero. Q_o depends upon the spectral composition of the star radiation. For a radiation with a spectral distribution similar to the sun the number of photons per square meter second within the wavelength range between 0.29 μ and 1.45 μ is (Gebel, 1958)

$$Q_o = 8.7 \cdot 10^{10}. \tag{7}$$

According to elementary geometric optics, the star image diameter is zero, if the distance of the star can be considered infinite (point source), which is always the case with fixed stars. Actually, however, the image at the focal plane has a finite diameter, D_i, which is determined by one of the following phenomena, whichever yields larger values:

(*a*) *Diffraction effect:* According to a well known formula the diameter, D_i, in meters of the star image at the focal plane is

$$D_i = 1.22 \cdot 10^{-6} \cdot \lambda_{max} \cdot \frac{f_T}{D} \tag{8}$$

if the wave length, λ_{max}, is in μ (micron), f_T is the focal length of the telescope objective and f_T and D are in the same dimensions.

(*b*) *Atmospheric effect:* Owing to rapid fluctuations of the density gradiant of the atmosphere, the instantaneous star image rapidly oscillates about its average position, or due to scattering of the star light caused by haze, the average image of the star appears larger. According to Eq. (8), the apparent diameter, D_i, in meters of the star image is

$$D_i = \alpha \cdot f_T \tag{9}$$

where α is the apparent oscillation angle (in radians) of the light beam arriving from the star, or the increase of the stars angular size caused by scattering of the light due to haze, or the true angular size of the celestial object (planet, satellite, missile, etc.) and f_T is the focal length of the telescope objective in meters.

Obviously, Eq. (5) is valid only up to a certain apparent star magnitude, which may cause saturation in the device. However, this is not important here because we shall consider only lower values of e_s since this paper is concerned principally with the value of the threshold magnitude which is possible to be detected.

According to the quantum theory, the scanning beam does not consist in a regular, homogeneous, flow of electrons, but of an irregular motion of individual electrons, each of which has a velocity more or less deviating from the average velocity. It is generally assumed and accepted as a rule, in accordance with statistical methods, that the root mean square of the electron current density fluctuations is, in the average, numerically equal to the square root of the mean electron current density. The same is usually assumed for the photon flux distribution.

Because of the velocity distribution in the scanning beam and the low velocity scan operation of an image orthicon only a fraction of the electrons in the scanning

beam fulfill the requirement necessary to land on the target plate and to discharge it. Also the percentage of electrons available in a beam for discharge is not a constant percentage but a direct function of the target charge. Hence, the return beam differs very little from the scanning beam and has, for operations with sufficient illumination available for optimum performance, an approximate value of 90% of the scanning beam, and at light levels below threshold of the image orthicon it becomes nearly 100% of the scanning beam.

Now, the number of electrons in the return beam, e_r, for the time duration the scanning beam is remaining on one resolution element may be assumed to be practically equal to the difference of the number of electrons in the scanning beam, e_{sc}, and the number of the stored positive charges, e_t, thus, the difference of two fluctuating quantities. This difference is a fluctuating quantity, too.

$$e_r = e_{sc} - e_t. \tag{10}$$

The ratio of the difference between the scanning beam, e_{sc}, and the return beam, e_r, to the scanning beam is usually called the orthicon beam modulation factor, m, where

$$m = \frac{e_{sc} - e_r}{e_{sc}}. \tag{11}$$

The usual value of this beam modulation factor under light conditions above threshold and a possible arrangement for determining it is treated in a supplement to this paper.

Since the scanning beam contains a much larger number of electrons than the number of stored positive charges existing on the target plate we will neglect, in the further calculations of Part I the fluctuations of the target plate charge and consider only the fluctuations of the scanning beam as the limiting factor of detection.

Now, it is evident that a small quantity, x, locally superimposed upon a fluctuating large quantity, $y \pm \Delta y$, will be easily confused with one of the fluctuation peaks, Δy, of the latter, if x is not substantially larger than the effective mean value, Δy_m, of the fluctuation. The latter was formerly shown under the used assumption, to be numerically equal to $y^{1/2}$. Thus, a necessary, but not necessarily sufficient, condition of detectability and assumed arbitrarily as threshold in this paper is

$$x = y^{1/2} \tag{12}$$

which, for our case, will require for the above assumed condition the expression

$$e_t = e_s(S-1) = e_{sc}^{1/2}, \tag{13}$$

where e_{sc} is the number of scanning beam electrons for each resolution element of the photocathode, and e_t the number of positive unit charges at the target plate. Obviously, the threshold or minimum detectable number of target charges will be smaller when fewer electrons are present in the scanning beam. However, the number of scanning beam electrons can only be reduced to a certain amount, because experience in operating image orthicons shows that there is a definite critical lower limit of the scanning beam current where, with a further reduction of beam intensity, regardless of the target charge, no modulated return beam seems to be produced, thereby establishing an operational threshold condition for the image orthicon. Above this threshold condition the minimum number of scanning beam electrons, e_{sc}, necessary to neutralize each specific target plate charge, e_t, is not obtained by multiplying e_t by a constant factor. This factor decreases as e_t increases.

$$e_{sc} = f(e_t). \tag{14}$$

By substituting Eq. (10) into Eq. (11) we obtain

$$m = \frac{e_t}{e_{sc}}. \tag{15a}$$

And in accordance with (14) and (15a)

$$m_{(e_t)} = \frac{e_t}{e_{sc}}. \tag{15b}$$

Since m is a function of e_t, and e_{sc} cannot be below a certain value or the image orthicon would not work at all, we are mostly interested in the smallest value of m, which we shall call the threshold modulation factor, m_{tr}, where we are still able to obtain usable information in the return beam with a signal to noise ratio in accordance with Eq. (12).

Now, we set as a criteria for further analysation for the threshold condition characterized by the mechanism by which the image orthicon operates in accordance to Eqs. (13) and (15).

$$e_t = e_{sc}^{1/2} = \left(\frac{e_{ttr}}{m_{tr}}\right)^{1/2} \tag{16}$$

where e_{ttr} is the smallest detectable number of charges at the target plate. Hence, the numerical value of m_{tr}.

$$m_{tr} = \frac{e_{ttr}}{e^2_{ttr}} = \frac{1}{e_{ttr}}. \tag{17}$$

This equation determines the threshold modulation factor, m_{tr}, for a signal to noise ratio in accordance to Eq. (12).

The time, t_e, necessary to collect a detectable target plate charge, e_{ttr}, may be calculated in accordance to Eqs. (5) and (17) for threshold conditions

$$m_{tr} = \frac{1}{e_{ttr}} = \frac{K}{Q_m \cdot D^2 \frac{\pi}{4} \cdot \eta_T \cdot \eta_P \cdot (S-1) \cdot t_e} = \frac{1}{Q_s \cdot \eta_P (S-1)} \tag{18}$$

From this equation we yield for the exposure time using a radiation similar to sunlight with Eqs. (6) and (7)

$$t_e = \frac{2.512^M \cdot K}{m_{tr} \cdot 8.7 \cdot 10 \cdot \frac{\pi}{4} \cdot D^2 \cdot \eta_T \cdot \eta_P (S-1)} \tag{19}$$

where t_e denotes the minimum exposure time necessary to collect on any resolution element of the target plate, a charge arbitrarily assumed detectable in accordance with Eq. (12).

To determine the threshold modulation factor of image orthicons used for this type of work the following calibration test may be made. The star is replaced by a light source of known intensity, thus replacing the star image on the photocathode with a spot of light. The spot size is controlled by masking the photocathode front glass with a diaphragm containing a very small aperture.

The illumination, I, of the photocathode by a light source of the intensity, C candles, at a distance of l feet from the diaphragm is

$$I = \frac{C}{l^2} \text{ft-c}. \tag{20}$$

According to accepted measurements, one foot candle radiating from a glowing body at 2870°K corresponds to 1.7×10^{18} photons per square meter second, for the spectral range between the wave lengths 0.29 μ and 1.45 μ

$$1\text{ft-c}_{2870°K} = 1.7 \cdot 10^{18} \frac{\text{photons}}{\text{m}^2 \text{ sec}}. \tag{21}$$

To approximately match the intensity of the illumination of the photocathode at the calibration to that produced by the star, a gray filter with constant attenuation factor of W is used. To establish the threshold condition, the distance between light source and diaphragm, and the scanning beam current is adjusted so that the average signal from the image of the diaphragm hole on the television screen is just detectable with a signal to scanning beam noise ratio as given by Eq. (12); at the same time, the scanning current must be kept on the verge of workability.

Under these conditions of the calibration test, the total number of photons, Q_s, absorbed by a resolution element of the photocathode becomes, according to Eqs. (2) and (21)

$$Q_s = 1.7 \cdot 10^{18} \cdot \frac{I}{W} \cdot D_r^2 \frac{\pi}{4} \cdot t_e \tag{22}$$

and using Eq. (4)

$$Q_s = 1.7 \cdot 10^{18} \frac{I \cdot D_i^2 \cdot \pi \cdot t_e}{W \cdot K \cdot 4}. \tag{23}$$

Hence, using Q_s from Eq. (22) in Eq. (18) we may compute

$$m_{tr} = \frac{4W}{1.7 \cdot 10^{18} I \pi D_r^2 \cdot \eta_P (S-1) \cdot t_e} \tag{24}$$

$$= \frac{7.5 \cdot 10^{-19} \cdot W}{I \cdot D_r^2 \cdot \eta_P \cdot (S-1) \cdot t_e}.$$

The easiest way to perform the callibration test is to scan the target plate continuously, therefore, in such a case t_e becomes the reciprocal value of the frame scanning rate, f_r, used for operating the image orthicon.

It must be kept in mind, however, that the threshold modulation factor m_{tr} found in Eq. (23) is valid only for the same conditions under which it was measured. A change in the frame scanning rate, bandwidth of the video amplifier, scanning beam width, etc. will effect the value of m_{tr}. The result is important because it serves later for determining the necessary preamplification in intensifier image orthicons. Further it is an important test result in itself, because the reciprocal value of m_{tr} represents the number of electrons in the scanning beam necessary to neutralize one positive charge at the target plate under assumed threshold conditions.

Numerical example I. Experimental determination of the threshold modulation factor:

A standard point light source (2870°K) with 8.7 candle power was placed at a distance of one foot before a wide spaced image orthicon RCA 73469, with a multialkali photocathode operated with a 2 Mcycles/sec bandwidth video chain. An aperture with a diameter of 0.155 mm was used. Threshold as defined in this paper was reached by placing a filter with an attenuation factor of 10^5 before the aperture.

The quantum efficiency of the photocathode was previously determined to be 0.006 for a color temperature of 2870°K by counting all the photons between λ min. 0.290 μ and λ max. 1.45 μ.

The secondary yield of the target plate was assumed to be 4. The area of the photocathode, 25 x 25 mm, was scanned continuously with 250 lines per frame with a non-interlaced frame rate of 40 per second.

$$D_r = \frac{25.10^{-3}}{250} = 10^{-4} \text{ m}.$$

Using Eq. (24) we find

$$m_{tr} = \frac{7.5 \cdot 10^{-19} \cdot 10^5}{8.5 \cdot (10^{-4})^2 \cdot 0.006 \cdot (4-1) \cdot \frac{1}{40}} = 2 \cdot 10^{-3}$$

which means the scanning beam has to have, for each charge to be neutralized at the target plate, 500 electrons to fulfill the above condition.

Since m_{tr} may be determined experimentally it is useful to rewrite Eq. (19) in order that, from this equation, we may determine the apparent star magnitude, M_{tr}, which may be sensed by the image orthicon under the threshold definition assumed by Eq. (12)

$$M_{tr} = 2.5 \log \frac{6.8 \cdot 10^{10} \cdot m_{tr} \cdot D^2 \cdot \eta_T \cdot \eta_P (S-1) \cdot t_e}{K}. \tag{25}$$

However, it must be noted that this equation is not valid if the exposure time, t_e, is extended so far that the dark current emission and the emission caused by the sky background are not of a negligible order in comparison to the scanning beam noise. An equation treating the latter situation will be derived in Part II.

Numerical example II.

A telescope with a 10-in. aperture is used in connection with an image orthicon closed circuit television chain. m_{tr} was determined to be 0.002 for a sweep frequency of 40 frames, for the tube employed and the chosen arrangement. The target plate employed permits an effective storage of the charge for 1 second with an efficiency, η_{te}, of 50 percent. The transmission efficiency of the refractor telescope is 0.7. The photocathode efficiency is 0.04 for a spectral distribution similar to sunlight (λ 0.29 μ to 1.45 μ). The spectral distribution of the star to be recorded has a radiation similar to that of the sun. As a result of seeing conditions, the star image covers 10 resolution points of the photocathode. The secondary emission yield of the target plate is assumed to be 4. Then, from Eq. (25)

$$M_{tr} = 2.5 \log \frac{6.8 \cdot 10^{10} \cdot 0.002 \cdot 0.25^2 \cdot 0.7 \cdot 0.04(4-1)(1 \cdot 0.5)}{10}$$

$$= 11.4$$

PART II

Image Orthicon with Intensifiers

In astronomical photography the primary reason for amplification is to increase sensitivity, so as to obtain a reduction of exposure time. If part of the amplification is ahead of the scanning process, it is called preamplification. In this case, the fluctuations (noise) of the photo-electron emission from the photocathode, plus the statistical and spontaneous fluctuation of the photocathode dark current, are amplified as well as the electron current due to the signal portion of the star radiation. To this preamplified primary noise is added the noise in the scanning beam. Then, the relative dominance of these two noises in the return beam determines which one is the limiting factor for detection. Which noise is dominant is affected by the amount of preamplification used.

Preamplification with intensifiers improves the detectability because very weak signals from the photocathode, provided they are stronger than the primary noise, can be amplified to such an extent that they are stronger than the scanning beam noise and, hence, can be detected. In pickup tubes without sufficient preamplification such weak signals would be weaker than the scanning beam noise and, therefore, unrecognizable. However, an unfavorable effect of preamplifier stages consists, usually, in an impairment of resolution. This raises objections to the use of too many cascaded preamplifier stages. This section of the report shows how to find a reasonable preamplification factor.

The secondary emission of the target plate is a kind of preamplification; however, in most cases it is insufficient. In the intensifier image orthicon (fig. 2) the photo-electrons impinge on one or more intensifier screens placed between the photocathode and the target plate. Each of these intensifier screens consists of several layers, including an aluminized phosphor layer and a contiguous photocathode. The phosphor layer reconverts the electronic image emitted by the

primary photocathode into an optical one, and the contiguous photocathode produces an amplified electronic image which is projected either upon the target plate or upon the next intensifier screen. In the present state of the art, the rate of preamplification of each intensifier screen may exceed 10; thus, a rate of 100 may be exceeded with two intensifier stages.

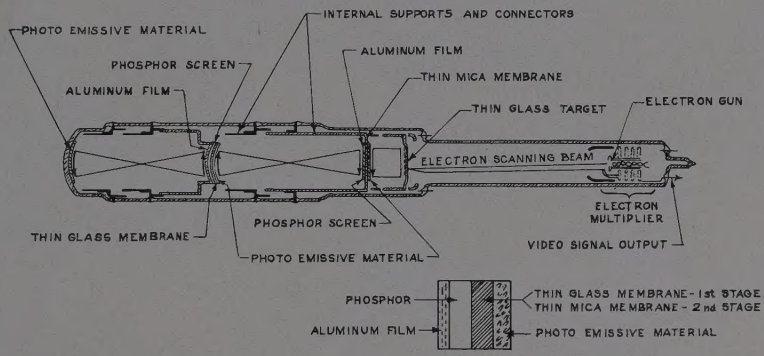

FIGURE 2. RCA two-stage intensifier image orthicon.

If, in Eq. (25), which computes the detectable star magnitude, M_{tr}, the preamplification factor, V, is incorporated, we obtain M'_{tr}.

$$M'_{tr}=2.5 \log \frac{6.8 \cdot 10^{10} \cdot m_{tr} \cdot D^2 \cdot \eta_T \cdot \eta_P \cdot V(S-1)t_e}{K}. \tag{26}$$

This equation is valid as long as the emission caused by the sky background, e_B, plus the photocathode dark current emission, e_D, may be neglected because it is sufficiently smaller than the emission caused by the starlight, e_s. The fluctuations of e_s are also neglected in this equation.

The smallest detectable number of target plate charges, e_{ttr}, in accordance with Eq. (17), is the reciprocal value of the threshold modulation factor. Then, V has an upper limit, V_{lim}, because if one electron during the selected exposure time is released by the chosen area of resolution of the photocathode

$$V_{lim} \cdot (S-1)=\frac{1}{m_{tr}}=e_{ttr}, \tag{27}$$

then, by neglecting the fluctuations in the photocathode emission, this one electron would produce the necessary target charge to be detected in accordance with Part I.

Hence,

$$V_{lim}=\frac{1}{m_{tr} \cdot (S-1)}. \tag{28}$$

Since the validity of Eq. (26) is limited, it is of interest to find the preamplification factor, V_{max}, where the emission, e_n, which is the summation of the dark current emission, e_D, plus the emission, e_B, caused by the sky background radiation, Q_B, at the photocathode will be detected by selected exposure times by the threshold condition assumed in Part I. We may write for this condition the following equation:

$$e_n \cdot V_{max}(S-1)=e_{ttr}=\frac{1}{m_{tr}}, \tag{29}$$

where

$$e_n=e_D+e_B. \tag{30}$$

The number of electrons, e_B, caused by the sky background for the total exposure time occurring at any element of resolution may be derived as follows: If the brightness of the sky background, B_B, is known in foot-Lamberts, the illumination, E_B, at the photocathode is expressed by the following equation in foot-candles:

$$E_B = 0.25 \cdot B_B \cdot \frac{D^2}{f_T^2} \cdot \eta_T. \tag{31}$$

Since 1 ft-c from a source with a color temperature of the sun is equal to approximately $3 \cdot 10^{17} \frac{\text{Quanta}}{\text{m}^2 \text{ sec}}$, counting the photons for a range from $0.29\,\mu$ to $1.45\,\mu$, we may rewrite the equation for obtaining the flux of photons, Q_F, per m^2 sec at the focal plane as follows:

$$Q_F = 7.5 \cdot 10^{16} \cdot B_B \cdot \frac{D}{f_T^2} \cdot \eta_T; \tag{32}$$

and if e_B' is the number of electrons caused by the sky background emitted by the photocathode per mm^2 sec, we may write

$$e_B' = 7.5 \cdot 10^{10} \cdot B_B \cdot \frac{D^2}{f_T^2} \cdot \eta_T \cdot \eta_P. \tag{33}$$

Further, if A is the number of resolution elements per mm^2, the number of electrons, e_B, caused by the sky background and released by the photocathode at any element of resolution during the selected exposure time are

$$e_B = \frac{10^{-6} \cdot Q_F \cdot \eta_P \cdot t_e}{A}. \tag{34}$$

Eqs. (32) and (33) used in Eq. (34) yield

$$e_B = \frac{7.5 \cdot 10^{10} \cdot B_B \cdot D^2 \cdot \eta_T \cdot \eta_P \cdot t_e}{A \cdot f_T^2} = \frac{t_e}{A} \cdot e_B'. \tag{35}$$

If e_D' is the dark current of the photocathode per mm^2 sec (usually 2000 electrons per mm^2 sec for multialkali photocathodes at 300°K), we derive for the dark current emission component, e_D, released by any element of resolution during the chosen exposure time

$$e_D = \frac{e_D' \cdot t_e}{A}. \tag{36}$$

Eq. (30), by using Eqs. (33), (35), and (36), may then be rewritten

$$e_n = \frac{t_e}{A}\left(e_D' + 7.5 \cdot 10^{10} \cdot B_B \cdot \frac{D^2}{f_T^2} \cdot \eta_T \cdot \eta_P\right) \tag{37}$$

$$= \frac{t_e}{A}(e_D' + e_B').$$

If we designate with e_n' the emission per mm^2 sec from the photocathode not caused by the stars radiation, we may write for our assumption from Eq. (37)

$$e_n' = e_n \cdot \frac{A}{t_e} = e_D' + 7.5 \cdot 10^{10} \cdot B_B \cdot \frac{D^2}{f_T^2} \cdot \eta_T \cdot \eta_P. \tag{38}$$

Eq. (36) substituted in Eq. (29) yields, for the defined maximum preamplification factor, V_{max},

$$V_{max} = \frac{A}{t_e\, m_{tr}(S-1)\left(e_D' + 7.5 \cdot 10^{10} \cdot B_B \cdot \frac{D^2}{f_T^2}\eta_T \cdot \eta_P\right)} = \frac{A}{t_e \cdot m_{tr}(S-1)e_n'} \leqq V_{lin}. \tag{39a}$$

V_{max} of Eq. (39a) just permits detection of the photocathods emission, e_n, and shows that the maximum preamplification factor, V_{max}, decreases with an increase

of exposure time, an increase of photocathode dark current, and an increase of the telescope aperture.

In other words, small telescopes and cooled photocathodes will require a tube with a higher preamplification factor to reach the arbitrarily assumed threshold of Eq. (26) than larger telescopes such as the 200-in. reflector at Mount Palomer.

If, in Eq. (39) V_{max} becomes larger than V_{lim}, the exposure time, t_e, would be too short for the average emission, e_n, of the photocathode to produce one electron. However, a V larger than V_{lim}, by employing short exposure times, can be useful as long as the source to be detected causes a few electrons to be emitted for each area of resolution of the photocathode during the chosen exposure time.

Numerical example III.

A telescope with an aperture of 500 cm is used, and the original f/15 m is extended to an effective f/50 m. The pick-up tube is a two-stage intensifier image orthicon with a preamplfication gain, V, of 100; the target mesh assembly is wide-spaced and a multi-alkali photocathode is used.

$$A = 100,\ \eta_T = 0.05,\ \eta_P = 2000 \text{ electrons/mm}^2 \text{ sec.}$$

$$m_{tr} = 0.002,\ S = 4,\ B_B = 10^{-4} \text{ ft-L.}$$

To determine the shortest exposure time just permitting detection of e_n in accordance with the definition of m_{tr} by rewriting Eq. (39) and $V = V_{max}$,

$$t_e = \frac{A}{V_{max} \cdot m_{tr}(S-1)(e'_D + 7.5 \cdot 10^{10} B_B \frac{D^2}{f_T{}^2} \cdot \eta_T \cdot \eta_P)} = \frac{A}{V_{max} \cdot m_{tr}(S-1)e'_n} \tag{39b}$$

$$= \frac{100}{100 \cdot 0.002 \cdot (4-1)(2000 + 7.5 \cdot 10^{10} \cdot 10^{-4} \cdot \frac{5^2}{50^2} \cdot 0.5 \cdot 0.05)} = 0.043 \text{ sec.}$$

Detection of Faint Stars in the Presence of a Sky Background Brighter than the Stars

In the situation expressed by Eq. (26), using V as expressed by Eq. (39), it was arbitrarily assumed that a limit in detection exists when the average photocathode current from the sky background and the average dark current just produces a detectable target charge, e_{ttr}.

As already explained in Part I, Eq. (12), the probability to detect a signal, x, superimposed over a fluctuating value, $y \pm \Delta y$, depends on the ratio $\delta = \frac{x}{\Delta y_{max}}$; and since we assumed a Poisson distribution for $y \pm \Delta y$, we must have $\delta = \frac{x}{y^{1/2}}$. It was assumed further that the "threshold" value of ratio δ is 1; i.e., the signal becomes detectable as soon as δ becomes 1, which is, of course, a rather favorable assumption. In reality, the probability of detecting a signal is a function of and increases asymptotically with δ.

The recording of celestial pictures using a telescope followed by a light amplifying system consists of a sequence of steps. The characteristic ratio, δ, may decrease after each step because of the possibility that fluctuations are introduced during such steps.

The ratio, δ, is a maximum for the number of photons from star radiations, Q_s, to the fluctuations in the number of photons from the sky background radiation, Q_B

$$\delta_{max} = \delta_{LF} = \frac{Q_s}{Q_B{}^{1/2}}, \tag{40}$$

where

$$Q_B = \frac{Q_F \cdot t_e}{A}. \tag{41}$$

After conversion of the light into electrons, δ is decreased because the conversion factor is smaller than 1 and the statistical fluctuations have to be calculated from the smallest number involved.

δ may be further decreased because of the possibility that noise is added in the amplifying system.

The first part dealt with a ratio of the target plate charge to statistical fluctuations in the scanning beam, δ_{sc}, neglecting all other noise sources and noted that

$$\delta_{sc} = \frac{e_t}{e_{sc}^{1/2}}. \tag{42}$$

Let us now assume the task of detecting a faint star against a much brighter, but homogeneous, sky background. It is possible, with an assumed ideal electronic device, to suppress the portion of the signal which corresponds to the average value of the sky background; but the statistical fluctuations in the signal from the background will determine the limit in detection. The probability, then, to detect the star radiation, with such an ideal arrangement, is a function of the ratio of the photocathode emission caused by the star to the statistical fluctuations in the emission caused by the sky background plus the photocathode dark current emission.

Consider the simplified condition

$$\delta_P = \frac{e_s}{e_n^{1/2}} \tag{43}$$

and neglect other noise sources. The signal, e_s, is constituted by the number of electrons produced by the radiation of the star for each resolution element during the chosen exposure time, t_e, while the fluctuations of e_n will be represented by the square root of the summation of the number of electrons caused by the radiation from the sky background plus the photocathode dark current emission. Evidently δ increases if e_s and e_n are multiplied by the same factor. This may be done by increasing the telescope aperture, by increasing the conversion yield of the photocathode, and also by extending the time duration of collecting photons. The latter is very important if stars with a radiation weaker than the background radiation of the universe have to be detected.

The fluctuation, $e_n^{1/2}$, in the photocathode emission, e_n, cannot be detected and, therefore, becomes the limiting factor, unless by employing preamplification the corresponding target charge fluctuations can be made sufficiently larger than the fluctuations in the scanning beam.

However, in view of the loss of resolution caused by the preamplifier stages, it is advisable to exceed only slightly that degree of preamplification at which the threshold of detectability due to scanning beam noise becomes equal to the fluctuations in the conversion at the photocathode of the sky background radiation plus the fluctuations of the dark current. Thus, the "critical" preamplification factor, V_{crit}, recommended is that for which the bottleneck for detectability changes over from the limitations determined by the scanning beam fluctuations to that of the photoelectron transformation plus dark current fluctuations, if the noise sources after the scanning process may be neglected.

Therefore, we may write the following equations in accordance with Eq. (13).

$$e_n^{1/2} \cdot V_{crit} = e_{sc}^{1/2} = \left(\frac{e_t}{m}\right)^{1/2} \tag{44}$$

$$V_{crit} = V'_{crit}(S-1). \tag{45}$$

Furthermore, since

$$e_n \cdot V_{crit} = e_t, \tag{46}$$

we may rewrite Eq. (44)

$$e_n^{1/2} \cdot V_{crit} = \left(\frac{e_n \cdot V_{crit}}{m}\right)^{1/2}.$$

Hence,

$$V'_{crit} = \frac{1}{m(S-1)}. \tag{47}$$

But since m is a function of e_t, V'_{crit} becomes a function of e_n. Also, the smallest possible value by definition for m was m_{tr} and, hence,

$$V'_{crit\ max} = \frac{1}{m_{tr}(S-1)}. \tag{48}$$

This equation corresponds to Eq. (28) and is logical because the smallest detectable number of charges at the target plate is $\frac{1}{m_{tr}}$, and if $V_{crit} = \frac{1}{m_{tr}}$, this charge would be caused by one electron, and the fluctuation would be $1^{1/2} = 1$, which is 100 percent, thereby making the fluctuations of e_n at the target plate equal to the fluctuations of e_{sc}.

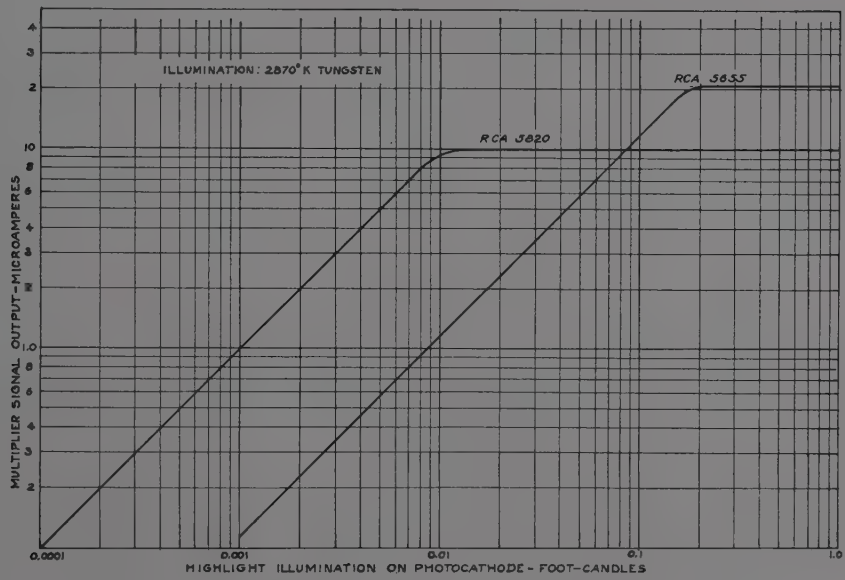

FIGURE 3. Typical signal output characteristics for image orthicon RCA 5655 and 5820.

Since, in accordance with statistics, the detectable percentage change in the average number of charges between the different resolution elements of the target plate depends on the total average number of charges involved, the target plate should have a storage capacity as large as possible. However, since the statistical fluctuations that occur are determined by the smallest number of particles involved, which is expressed in our case by the ratio, δ_P, for the condition of the emission at the photocathode, preamplification should be used only in as far as it increases the target charge sufficiently to overcome the scanning beam noise. Use of a

higher preamplification factor will not produce a gain in detection; on the contrary, the target plate will become saturated unnecessarily fast, which means that the otherwise permissible longer exposure time is shortened. However, for a given astronomical instrumentation and for a given δ_P in Eq. (41), e_s has to be increased only by the half power of e_n or, if the exposure time is extended by a factor one hundred, a star ten times fainter can be detected (a gain of 2.5 magnitudes).

In reference to the foregoing it is, therefore, necessary to investigate, for the present state of the art, the maximum number of charges, $e_{t\ max}$, that can be stored on an image orthicon target plate.

The RCA image orthicon 5655 has a very close-spaced target plate where the meshwire is nearly in contact with the target plate. Charge saturation of the target plate of an image orthicon is indicated by the knee of the light transfer characteristic curve. The knee of the 5655 characteristic is at a highlight illumination, E_K, of 0.2 ft-c ($\lambda = 290 m\mu$ to 1.45 μ; sunlight) (fig. 3) on the photocathode. Hence, the following number of charges, $e'_{t\ max}$, during each frame of scanning which may be stored at the target plate for each mm^2 photocathode area exposed, just reaching saturation is

$$e'_{t\ max} = \frac{E_K \cdot 3 \cdot 10^{11} \cdot \eta_P \cdot (S-1)}{f_r}, \tag{49}$$

and in the case for the 5655 image orthicon target plate, the maximum number of stored charges per mm^2 area of the photocathode during the exposure time would be

$$e'_{t\ max} = \frac{0.2 \cdot 3 \cdot 10^{11} \cdot 0.03 \cdot (4-1)}{30} = 1.8 \cdot 10^8. \tag{49a}$$

The 5655 orthicon has a beam modulation factor, m_{max}, of 10% if operated at the knee. The secondary emission yield is 4.

Therefore, in accordance with Eq. (47), the critical preamplification factor for making the background noise equal to the beam noise for a target plate as the 5655, if operated at the knee, is

$$V'_{crit(5655)} = \frac{1}{m(S-1)} = \frac{1}{0.1(4-1)} = 3.3, \tag{49b}$$

which can easily be achieved with the present state of the art in making intensifier stages.

The maximum permissible photocathode emission, e'_n, per mm^2 sec caused by the stray light and the dark current, which will just start to saturate the target plate of a tube using preamplification for overcoming the scanning beam noise, will in accordance with Eq. (46) and Eq. (48) be

$$e'_n = \frac{e'_{t\ max}}{V'_{crit}(S-1)t_e}; \tag{50}$$

and by using Eqs. (45), (42) and (50), assuming perfect storage, we may equate for the maximum exposure time, $t_{e\ max}$, in seconds that produces a target plate charge just leading to saturation

$$t_{e\ max} = \frac{e'_{t\ max}}{V'_{crit}(S-1) \cdot e'_n} = \frac{e'_{t\ max} \cdot m}{e'_n}. \tag{51}$$

Numerical example IV.

An intensifier image orthicon is used with a telescope having a 500-cm aperture and a 50-m effective focal length. The target plate-meshwire arrangement is similar to that in the 5655 orthicon with an $e'_{t\ max}$ of $1.8 \cdot 10^8$; and it is assumed that the target plate can store and integrate over several hours without loss of resolution, that the beam modulation factor at the knee is 10%, and that the

secondary emission yield is 4. Then, from Eq. (47) for numerical values of e'_D, B_B, η_T, η_P, as in example III

$$V'_{crit}=\frac{1}{m(S-1)}=\frac{1}{0.1(4-1)}=3.3.$$

Then, according to Eq. (38)

$$e'_n=(2000+7.5\cdot 10^{10}\cdot 10^{-4}\frac{5^2}{50^2}\cdot 0.5\cdot 0.05)=3875,$$

and from Eq. (51)

$$t_{e\ max}=\frac{1.8\cdot 10^8\cdot 0.1}{3875}=4650 \text{ sec.}$$

The star magnitude which can be recorded under the previous assumptions by the present state of the art with an intensifier image orthicon in the presence of the sky background and the photocathode dark current for a chosen δ_P may be derived by rewriting Eq. (43)

$$e_s=\delta_P\cdot e_n^{1/2}.$$

Using Eq. (5) for e_s in the above

$$Q_m\cdot D^2\cdot\frac{\pi}{4}\cdot\eta_T\cdot\eta_P\cdot\frac{t_e}{K}=\delta_P\cdot e_n^{1/2}. \tag{52}$$

In accordance with Eq. (46) we may write

$$e_n=\frac{e_{t\ max}}{V'_{crit}(S-1)}=\frac{e'_{t\ max}}{A\,V_{crit}}. \tag{53}$$

Substituting for e_n in Eq. (52) with Eq. (53), by neglecting the much smaller additional charge caused by the star radiation which is also stored on the target plate, we find for Eq. (52)

$$Q_M\cdot D^2\cdot\frac{\pi}{4}\cdot\eta_T\cdot\eta_P\cdot\frac{t_e}{K}=\delta_P\left(\frac{e'_{t\ max}}{A\cdot V'_{crit}(S-1)}\right)^{1/2}. \tag{54}$$

Substituting t_e with Eq. (51) gives

$$\frac{Q_M\cdot D^2\cdot\frac{\pi}{4}\cdot\eta_T\cdot\eta_P\cdot e'_{t\ max}}{K\,V'_{crit}(S-1)e'_n}=\delta_P\left(\frac{e'_{t\ max}}{A\cdot V'_{crit}(S-1)}\right)^{1/2},$$

and rewriting this yields

$$Q_M\cdot D^2\cdot\frac{\pi}{4}\cdot\eta_T\cdot\eta_P\cdot\frac{e'^{1/2}_{t\ max}\cdot A^{1/2}}{K[V'_{crit}\cdot(S-1)]^{1/2}\cdot e'_n}=\delta_P. \tag{55}$$

Assuming radiation similar to sunlight and $\lambda=0.29\ \mu$ to $1.45\ \mu$, we may substitute Q_M in Eq. (55) in accordance with Eqs. (6) and (7) with

$$Q_M=\frac{8.7\cdot 10^{10}}{2.512^M}.$$

Then, we find for the faintest magnitude which can be detected using an intensifier image orthicon with the assumptions previously made,

$$M_{limit}=2.5\log\frac{6.8\cdot 10^{10}\cdot D^2\cdot\eta_T\cdot\eta_P\cdot e'^{1/2}_{t\ max}\cdot A^{1/2}}{\delta_P\cdot K[V'_{crit}(S-1)]^{1/2}e'_n}. \tag{56}$$

This equation contains no factor for the exposure time, because the exposure time cannot be extended beyond the storage capability of the target plate; however, it is assumed that the correct exposure time is available for just collecting the necessary maximum charge, $e'_{t\ max}$. The value for this exposure time may be

calculated by using Eq. (51), and exposure beyond this value will not detect a fainter magnitude star, due to saturation of the target plate.

Numerical example V.

In numerical example IV the theoretical maximum exposure time was calculated to be 4650 sec. The faintest apparent star magnitude may then be calculated with Eq. (56), assuming $\delta_P = 2$ and a coverage factor of 5 resulting from air scintillations. Hence,

$$M_{limit} = 2.5 \log \frac{6.8 \cdot 10^{10} \cdot 5^2 \cdot 0.5 \cdot 0.05 \cdot (1.8 \cdot 10^8 \cdot 100)^{1/2}}{2 \cdot 5 \left[3.3 \cdot (4\text{–}1)\right]^{1/2} \cdot 3875} \approx 27.$$

It may be of interest to determine as a figure of merit, the theoretical magnitude, M_{FM}, which could be achieved if there were no sky background radiation. If one assumes sufficient storage of the charge image, the determining factor for the limiting magnitude would then be the photocathode dark current emission, e_D', which may be assumed to be reduced by cooling to 35 electrons/mm² sec. Then, if

$$e_n' = e_D' = 35;\ \delta_P = 1;\ K = 1;\ D = 5;\ \eta_T = 0.5;\ \eta_P = 0.05;$$
$$A = 100;\ V_{crit} = 10;$$
$$M_{FM} = \frac{6.8 \cdot 10^{10} \cdot 5^2 \cdot 0.5 \cdot 0.05 \cdot (1.8 \cdot 10^8 \cdot 100)^{1/2}}{1 \cdot 1 \cdot 10^{1/2} \cdot 35} \approx 34.$$

The previous calculations were made assuming maximum performance, where the tube is operated at the knee of the light transfer characteristic, which means that the target plate is just approaching saturation. It is now of interest to calculate for a more practical situation the apparent star magnitude M_{pract}. This is the situation where the amount of star light available and the chosen exposure time will determine a point of operation below the knee of the charge transfer characteristic; i.e., below saturation of the target plate. From Eqs. (38) and (52) we may write (for radiation similar to sunlight),

$$\frac{8.7 \cdot 10^{10}}{2.512^M} \cdot D^2 \cdot \frac{\pi}{4} \cdot \eta_T \cdot \eta_P \cdot \frac{t_e}{K} = \delta_P \cdot e_n'^{1/2} = \delta_P \left(\frac{e_n' \cdot t_e}{A} \right)^{1/2}$$

and from this the apparent star magnitude

$$M_{pract} = 2.5 \log \frac{6.8 \cdot 10^{10} \cdot D^2 \cdot \eta_T \cdot \eta_P \cdot t_e^{1/2} \cdot A^{1/2}}{\delta_P \cdot K \cdot e_n'^{1/2}}. \tag{57}$$

Numerical example VI.

A telescope with a 10-in. aperture and a f/15 m is used with an intensifier image orthicon system. Perfect storage and tracking is assumed for an exposure time of 30 min. $e_D' = 2000$ electrons/mm² sec.

$$B_B = 10^{-4} \text{ ft-c};\ \eta_T = 0.5;\ \eta_P = 0.05;\ m = 0.05.$$
$$A = 100;\ K = 5;\ \delta_P = 2;\ S = 4.$$

Hence, from Eq. (38)

$$e_n' = 2000 + 7.5 \cdot 10^{10} \cdot 10^{-4} \cdot \frac{0.25^2}{15^2} \cdot 0.5 \cdot 0.05 = 2052;$$

and the maximum charge at the target plate from the dark current plus the background, from Eq. (51) is

$$c_{t\,max}' = \frac{e_n' \cdot t_e}{m} = \frac{2052 \cdot 1800}{0.05} = 7.4 \cdot 10^7 \frac{\text{charges}}{\text{mm}^2}.$$

This value is possible with a target plate mesh assembly like that in the 5655, and the star magnitude calculated as in Eq. (57).

$$M_{pract} = 2.5 \log \frac{6.8 \cdot 10^{10} \cdot 0.25^2 \cdot 0.5 \cdot 0.05 \cdot (1800 \cdot 100)^{1/2}}{2 \cdot 5 \cdot 2052^{1/2}} \approx 20.$$

The preamplification necessary is in accordance with Eq. (47)

$$V'_{crit} = \frac{1}{m \cdot (S-1)} = \frac{1}{0.05 \cdot (4-1)} = 6.6,$$

which is easily achieved by the present state of the art, with a single stage intensifier image orthicon.

CONCLUSIONS

The previous calculations demonstrate the theoretical possibility to photograph faint celestial bodies of 34th magnitude. The faintest star ever recorded with an image device was of 24th magnitude and this was achieved with the 200-in. Mount Palomar reflector. The necessary specifications of the intensifier image orthicon are feasible with our present technological knowledge. However, different telescope arrangements, tasks, and exposure times require different tube specifications. The most important feature of the pick-up tube, for such an endeavor, is the storage target plate. The target plate must have the same, or higher, capacity as the target plate of the R.C.A. 5655 image orthicon, and permit effective storage and integration of the charge image over at least 80 minutes with a negligible loss of resolution or charge. Such a target plate is possible with the present technological knowledge; and further directed research should lead to the desired results, thereby permitting mankind the efficient detection of artificial earth satellites and the penetration deeper into the mysteries of space.

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APPENDIX—LIST OF SYMBOLS

- A Number of resolution elements per square millimeter at photocathode.
- B_B Brightness of sky background in foot-Lamberts.
- C Candle power of light source used for calibration test.
- D Diameter of telescope lens in meters.
- D_i Diameter of star image at focal plane (photocathode) in meters.
- D_r Diameter of one resolution element at focal plane in meters.
- E_B Illumination of photocathode in foot-candles caused by sky background.
- E_K Illumination of photocathode in foot-candles resulting in an operation of the image orthicon at the knee of the light transfer characteristic.
- I Illumination of photocathode in foot-candles for calibration test.
- K Coverage factor, indicating the number of resolution elements the star image occupies.
- M Apparent magnitude number of celestial body involved.
- M_{limit} Faintest apparent star magnitude detectable with the intensifier image orthicon depending on storage capability of target plate assuming optimum exposure time.
- M_{pract} Apparent star magnitude detectable with intensifier image orthicon using selected exposure time that operates image orthicon below knee of light transfer characteristic.
- M_{FM} Faintest apparent star magnitude theoretically detectable with the intensifier image orthicon by assuming ideal conditions, cooling the photocathode, and neglecting sky background radiation.

M_{tr} Apparent star magnitude by neglecting background and dark current emission just producing detectable charge at target plate with image orthicon.

M'_{tr} Same as M_{tr}, but for intensifier image orthicon under defined conditions.

Q_B Number of photons arriving from sky background onto any resolution element of the photocathode during selected exposure time.

Q_F Photon flux at focal plane per square meter·second.

Q_M Photon flux of star radiation per square meter·second for apparent star magnitude M.

Q_o Number of photon per square meter·second for apparent star magnitude O.

Q_s Number of photons from star radiation onto any resolution element occuring during selected exposure time.

S Secondary emission factor of target plate.

S–1 Effective secondary emission yield multiple of target plate.

V Preamplification factor of intensifier stages.

V_{crit} Critical preamplification factor of intensifier stages including gain by secondary emission at target mesh wire assembly, where fluctuations of e_n are equal to fluctuations of e_{sc}.

V'_{crit} Critical preamplification factor of intensifier stages.

V_{lim} Preamplification factor before target meshwire structure to produce at target plate a detectable charge caused by one electron emitted by the photocathode.

W Attenuation factor of gray filter used for calibration test.

e_B Number of electrons emitted by the photocathode caused by sky background radiation occurring for any element of resolution during selected exposure time.

e'_B Number of lectrons of photocathode emission per square millimeter per second exposure time caused by sky background radiation.

e_D Number of electrons of dark current emission from photocathode occuring at any element of resolution during selected exposure time.

e'_D Number of electrons of dark current emission from photocathode per square millimeter area per second exposure time.

e_n Number of electrons emitted by the photocathode that are not due to star radiation, but caused by sky background plus dark current emission occurring for any element of resolution during selected exposure time.

e'_n Number of electrons of photocathode emission per square millimeter per second exposure time caused by sky background radiation plus dark current emission.

e_r Number of electrons in image orthicon return-beam during selected time the scanning beams remains on one element of resolution.

e_s Number of electrons emitted by the photocathode owing to star radiation for any one element of resolution during selected exposure time.

e_{sc} Number of electrons of the scanning beam during the selected time the scanning beam remains on one element of resolution. The time the scanning beam remains on one resolution element is not identical with the exposure time.

e_t Number of positive unit charges on the target plate in any one element of resolution during selected exposure time.

$e'_{t\,max}$ Number of positive unit charges at target plate per equivalent square millimeter area of photocathode operating the image orthicon at knee of light transfer characteristic.

e_{ttr} Smallest detectable number of positive unit charges on the target plate.

f_T Focal length of telescope in meters.

f_r Frame scanning rate of image orthicon.

1	Distance of light source in feet; used in calibration test.
m	Orthicon beam modulation factor.
m_{tr}	Threshold beam modulation factor as defined in paper.
t_e	Selected time duration photons are collected (exposure time) in seconds.
$t_{e\ max}$	Exposure time that causes a charge at target plate which operates image orthicon at knee of light transfer characteristic.
α	Apparent angle of oscillation of the light beam arriving from the star, or increase in the stars angular size caused by scattering of the light due to haze or true angular size of the celestial objects (e.g., planets satellite, missile etc. in radians.
δ	Ratio of signal caused by star radiation to root mean square value (fluctuation) of signal portion not due to star radiation.
δ_{LF}	Ratio of number of photons from star radiation to root mean square value of number of photons from sky background.
δ_P	Ratio of number of electrons emitted by the photocathode owing to star radiation to root mean square value of number of electrons emitted by the photocathode that are not due to star radiation.
δ_{sc}	Ratio of number of charges at the target plate to root mean square value of number of electrons of the scanning beam which occur during the time the scanning beam rests on one element of resolution.
η_P	Photocathode quantum efficiency = average photon to electron conversion yield of photocathode.
η_T	Transmission factor of the telescope lens.
η_{te}	Efficiency factor for storage capability of target plate.
λ	Wavelength of light sensed in μ.

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CURRENT SOVIET OUTLOOK ON THE INHERITANCE OF ACQUIRED ADAPTATIONS*

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Lack of communication between biological scientists in the United States and in the Soviet Union has given rise to the notion here that the influence of Trofim D. Lysenko has declined, and that as a corollary the views of Lysenkoism in the Soviet Union have changed materially. Twenty years ago, T. D. Lysenko offered an explanation resembling Lamarck's to account for inheritance, and his report was approved by the Central Committee of the Communist Party, with the result that geneticists who deplored the acceptance of the report were relieved of their duties. Nikolai I. Vavilov was removed from the presidency of the Soviet Academy of Agricultural Sciences following his controversy with Lysenko (Vavilov, 1939). Vavilov disappeared from the public scene soon after 1939. However, early in 1956 the Soviet Academy of Science ordered a republication of Vavilov's works, apparently as a sign of the reversal of governmental attitude

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following the death of Premier Stalin (Times, 1956). This was interpreted in the United States as a lessening of Lysenko's influence.

My visit to the Soviet Union for five weeks during 1958, together with an examination of textbooks and correspondence with several American scientists interested in the status of genetics there, reveals that although some modifications of the views intensely hostile to "Western genetics" have transpired, and contradictions seem to exist between professed beliefs and actual practice, the acceptance of the gene concept has not occurred in the slightest degree. T. D. Lysenko appears to be more solidly entrenched than ever, and he is an important Communist Party official, having recently received again the Order of Lenin. Lysenko is head of the Institute of Heredity in Moscow, and is engaged in directing investigations designed to increase the production of milk by dairy cattle.

How extensively Lysenko's name and ideas have entered the fabric of the Soviet Union's outlook may be gauged in a number of ways. For example, there are 17 references to his work in a general biology textbook (Maxovko and Makarov, 1956). A new textbook for the tenth grade, used throughout the nation, entitled "Fundamental Darwinism," contains a lengthy discussion of Lysenko's contributions to Soviet science, with his picture (Veselov, 1958). Academician Lysenko is one of eight editors of a five-volume encyclopedia of agriculture; a revision of his 600-page "Agrobiologia," dated 1952, supersedes the 1948–9 edition (Lysenko, 1952). The methods advocated by Lysenko for improving plants by means of treating seeds, planting under unusual conditions and grafting to obtain new kinds of seeds, are an important part of a large methodology book for botany teachers (Verzilin, 1955), and his name even appears in a book for teachers of invertebrate zoology, published by the Academy of Pedagogical Science (Lozina-Lozinskovo, 1955). Furthermore, four of twelve essays dealing with "philosophical questions of natural science" (Kaganov et al., 1957) mention Lysenko, and a book of essays on dialectical materialism and natural science contains three essays citing his conclusions (Knazeba, 1957).

Some Americans have talked with Academician Lysenko in Moscow recently, but I was unsuccessful in my efforts to do so. The interpreter through whom arrangements were attempted was dubious from the start, saying, "You see, Lysenko is a very high Party member." It was disappointing not to visit his laboratories after V. M. Kaganov (1957) told me, "Academician Lysenko maintains his experiments with plants at his laboratories even today, and if you could see them, you would be convinced."

At one university, I posed questions about actual scientific support for Lysenkoism. One of four Soviet scientists present said that in this connection a group of investigators under the leadership of N. P. Dubinin was undertaking a "critical review" of the Lysenko position. It should be mentioned that abstracts and translations of journals of genetics are available to some investigators. The Russians quickly and vigorously respond to American articles which question Lysenko's techniques. In conversations, however, criticisms of these articles are comparatively mild; V. M. Kaganov said, "We were surprised at the suggestion that Lysenko's findings contained an element of political bias."

It was noticed that the former term, "Mendel-Morgan genetics," used with intense disapprobation a decade ago, has apparently been supplanted by "Goldschmidt-Morgan." Mendelism is, in its broadest meaning, acceptable. One of four color plates in a general biology textbook (Maxovko and Makorov, 1956) shows F_2 flowers as white, pink, and red, in the familiar 1:2:1 ratio; however, the text states, ". . . but Soviet scientists have improved upon this." The gene concept is unacceptable, since inheritance is believed to be a function of the entire cell contents, in what appears to be a Darwinian "pangene" concept. However, the existence of DNA was cited as evidence to *support* the Lysenkoists' stand.

Several questions grow out of the realization that T. D. Lysenko is still held in

high esteem and that his views are passed on to students and pupils in textbooks.

Does the rejection of "Western genetics" imply a rejection of plant breeding methods which have been eminently successful in the United States for corn and wheat? The fact that agronomists visiting the United States were exceedingly eager to obtain precise descriptions of crosses of the latest kinds introduces a puzzling inconsistency. However, the only evidence that theory and practice do not coincide is a fairly reliable report that in 1944 in Tashkent, Uzbekistan, colchicine was used to obtain new kinds of plants in crosses between Asian and American cotton.

Does the Lysenkoist view affect the "scientific attitude" of young people and the outlook upon phases of study beyond agricultural research?

It must be remembered that the basic assumptions inculcated by the educational system are unequivocal and oft-repeated. There is no inconsistency in textbooks, all of which emanate from publishing houses whose officials are, or are responsible to, Communist Party leaders. The teaching profession and scientific workers are members of a trade union of whose 4 million members forty percent are Party members. The Lysenkoist position is stated categorically.

While it is true that pupils are permitted to raise questions and criticize studies undertaken in the classroom, laboratory, and field station, the teachers themselves are not permitted to question the foundations of subjects presented in textbooks. If doubts were to arise in the case of heredity, it would be likely they would lead nowhere, simply because the basic assumptions which are given are unassailable by any evidence provided in textbooks or in the teachers' experience.

It is not a question of teachers suppressing knowledge, but one of having no other information which can be regarded seriously. How questions are handled in advanced courses is not known by the writer, but it is possible to "deny the existence" of genes by merely requiring a kind of evidence for their existence which cannot be presented. The very essence of dialectics is the creation of unassailable assumptions which form the basis, in the case of dialectical materialism, for action and extended reasoning sometimes contrary to circumstantial evidence, until the creation of new assumptions seems unavoidable. The preponderance of evidence favoring genes is, of necessity, circumstantial. "Western geneticists" find the concept exceedingly fruitful for practical applications and for extending ideas to higher levels with predictive results, whereas Lysenkoism, in its most favorable interpretation, satisfies itself with only that portion of the evidence tending to show that cells and organisms are more highly integrated and complex in their activities than hypothetical genes can wholly explain.

Does the rigid position taken about the gene concept overflow into ancillary scientific areas? Without question, the rejection of the idea of inheritable particles alters certain academic as well as scientific procedures. For example, there are no aptitude tests in the educational system. All school promotions and college entrance qualifications are based upon manifest performance in oral and written examinations. Guidance is based upon the expressed preferences of the pupil coupled with insight and the records kept by teachers. Lack of mental ability, in addition, is considered as a reflection of laziness rather than of imperfect inheritance. Defects of hearing as well as other malformations are viewed as postnatal in origin, or possibly as intra-uterine. Severe mental disturbances are believed to have no parental connection, although in one laboratory of defectology, an investigator said, ". . . but we are beginning to think there must be a strong connection."

From all appearances, there is actually an exceedingly high sense of accuracy, faithfulness to fact, and an eagerness to discover true relationships in nature, among people of all levels, and a very deep respect for science apart from the exceptions noted. To assume that the scientific fabric of the Soviet Union is verging on collapse because of bias in one area of it is to set the stage for a rude

awakening. There is even a slight gain accruing from explaining inheritance on the basis of the reactions of the whole organism to its environment: great effort is expended to test the potential adaptability of the germ plasm to its limits in environmental situations not normally encountered by a given plant or animal. Plants are tested incessantly; "sports" are sought after by thousands of school children on the experimental farms; animals, such as the sturgeon, are transplanted to assorted habitats without inhibition. Variations thus discovered are available for exploitation. How the variations occur does not hamper this work, of course. It is possible that the high yields of millet, said to have brought Lysenko his early fame, and by some reported to have made a very important contribution during the war, were obtained by these methods adopted from Luther Burbank's work in the United States; the same methods still give notable results, as in the development of a watermelon which ripens during the short growing season around Moscow, although the spherical melon may indeed be the result of a cross.

Lastly, it is probable that the best students in advanced biological science are not totally insulated from worldwide applications of the gene concept. It is likely that discussions of heredity are bound to touch upon the idea of the particulate nature of inheritable bodies and that, despite the basic assumptions which have grown up (every person under the age of forty-two has lived all his life under the aegis of these assumptions), there are opportunities for referring to genes, if only as improbable explanations.

The greater likelihood is, however, that the concern for scientific freedom about genetics expressed in America is not shared as intensely by scientists in the Soviet Union. Those who would perpetuate the concept of the gene are undoubtedly few, now, and it can be concluded that the issue itself is considered relatively unimportant upon the backdrop of the tremendous progress being achieved in areas of science not affected by the current outlook regarding the inheritance of acquired adaptations.

In the long run, production in agriculture might be jeopardized by the rejection of the gene concept. If that time arrives, there is no question in my mind, and I understand to some extent the basic assumptions of communism, as to the change that will thereupon occur. It is a maxim of communist philosophy that "Truth is absolute, but not final." This means, "What is believed today is very firmly believed, for it facilitates progress. But what is believed today need not resist all change, since a new absolute truth can arise tomorrow."

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SULFUR IN ROMAN BRASS

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In a previous paper (Caley, 1955) it was shown that the proportion of zinc in Roman coinage brass decreases progressively with time, and that this change is accompanied by an increase not only in the proportion of copper, but also in the proportions of tin and lead. A possible explanation of the chronological changes in the proportions of these metals was suggested.

The present investigation was undertaken to find out whether the proportion of sulfur in Roman coinage brass varies in any regular way with time. The possibility that it may do so is indicated by the results of some analyses of Bibra (1869), who found determinable amounts of this nonmetallic impurity in three coins struck in the second century A.D., but only traces or none at all in a few earlier coins. However, Bibra did not describe his analytical procedure in any detail, and there is at least one indication that it may have been defective.

Seventeen Roman brass coins of known date covering almost the entire period of issue of such coins were taken for analysis. The samples for analysis were prepared by filing away all exterior corrosion products from the coins and cutting out sectors of clean metal that weighed about a gram. The procedure used for the detection or determination of sulfur was especially devised for the purpose. Though based on established principles, it differs considerably from the usual procedures used for the determination of sulfur in modern copper alloys. For this reason, and because no detailed procedure for the determination of sulfur in any kind of ancient copper alloy appears ever to have been published, it is given here as a complete working procedure.

ANALYTICAL PROCEDURE

Accurately weigh a clean sample amounting to about 1 g. Place this in a 250-ml beaker, add 20 ml of concentrated nitric acid and cover at once with a watch glass. When action has ceased, place the beaker on a steam plate or low temperature hot plate and digest until all spray has been washed from the watch glass and sides of the beaker. Then place glass hooks under the watch glass and evaporate to 10 ml. Add water to bring the volume to 50 ml and digest on the steam plate or hot plate for about an hour. Macerate a quarter of a quantitative filter paper in water by shaking in a test tube, and add the mixture to the solution. Filter through a double quantitative paper of fine texture and wash the precipitate and filter at least 10 times with hot 1% nitric acid. Catch the filtrate and washings in a 250-ml beaker, add 10 ml of concentrated hydrochloric acid, cover with a watch glass supported by glass hooks and evaporate nearly to dryness on a hot plate. Add another 10 ml of concentrated hydrochloric acid and again evaporate nearly to dryness. Dilute with 50 ml of water. If the solution is not entirely clear, filter through quantitative paper, wash with small portions of water until the paper is colorless, and catch the filtrate and washings in a 250-ml beaker. Add dilute ammonium hydroxide solution cautiously until a small precipitate of copper hydroxide persists, and add dilute hydrochloric acid solution (1:4) cautiously until this precipitate just dissolves, then 5 drops more. Heat the solution nearly to boiling and add 10 ml of 1% barium chloride solution drop by drop over a period of 10 min while stirring. Cover the beaker with a watch glass and allow to stand at least 12 hr. The appearance of a white turbidity or precipitate indicates the presence of sulfur.

To determine the amount, heat the mixture nearly to boiling for about an hour

and filter through a weighed porcelain filter crucible. Wash with successive small portions of warm water until the washings become entirely colorless. Ignite at 500°C in a muffle for an hour. If the ignited precipitate is entirely white, cool and weigh to determine the weight of the barium sulfate. If it is discolored, cool the crucible and place it in a suction filtering apparatus arranged so that filtrate and washings may be caught in a 250-ml beaker containing 75 ml of water. Then, without turning on the aspirator, add with a pipet 1.0 ml of concentrated sulfuric acid drop by drop to the precipitate in the crucible. After the precipitate has dissolved turn on the aspirator and draw the solution through the crucible. Turn off the aspirator and add 0.5 ml of concentrated sulfuric acid to the crucible. After about half a min draw this wash acid through the crucible. Repeat with another 0.5 ml portion of acid. Wash the crucible rapidly with several small portions of water. Heat the filtrate containing the reprecipitated barium sulfate nearly to boiling and digest until the precipitate settles readily. Filter through a weighed porcelain filter crucible, wash with several small portions of water, ignite at 500°C in a muffle for about an hour, cool, and weigh. Multiply the weight of the precipitate by 0.1374 to obtain the weight of sulfur.

NOTES ON PROCEDURE

1. To avoid danger of loss from too violent action, the sample should be in the form of one or two large pieces rather than in the form of drillings.

2. If tin is absent as shown by the lack of a residue after concentration and dilution of the nitric acid solution, the hydrochloric acid may be added without the prior filtration. However, some tin is usually present in small amount.

3. The purpose of the double hydrochloric acid treatment is to destroy nitric acid, for erroneous results are obtained on precipitating barium sulfate in nitrate solution.

4. The hydrochloric acid solution should not be evaporated to dryness because it may be difficult to redissolve the salts completely without treatment with an excessive amount of acid.

5. Any turbidity or cloudiness in the solution after hydrochloric acid treatment is usually due to silver which is sometimes present in small amount. The silver chloride must be removed by filtration. Lead is usually present but not in sufficient amount to precipitate as chloride. However, if the amount is large enough, lead chloride will be precipitated at this point and must also be removed by filtration.

6. Usually the barium sulfate is contaminated by adsorbed copper and iron ions; hence the need for reprecipitation.

7. Barium sulfate is soluble in cold concentrated sulfuric acid due to the formation of a complex, whereas ferric oxide and to some extent cupric oxide are not. Addition of the barium sulfate solution to water causes an immediate reprecipitation of the barium sulfate.

8. The solution of the barium sulfate precipitate in the first portion of sulfuric acid must be washed through the crucible with additional portions of acid since immediate washing with water might cause reprecipitation of barium sulfate in the pores of the filter plate. However, the total volume of sulfuric acid must be restricted in the solution from which the barium sulfate is reprecipitated.

9. Since the barium sulfate is reprecipitated in a very finely divided state, the solution containing it must be heated near the boiling point for at least an hour so as to obtain a filterable precipitate.

10. The freedom of the reagents from sulfate should be tested by means of a blank determination. If any is found, this must be applied as a correction to the results obtained on samples. However, it is more preferable to select reagents that are free from detectable amounts of sulfate.

RESULTS AND CONCLUSIONS

The results are shown in table 1. Duplicate tests or determinations were made when sufficient uncorroded alloy was available. The satisfactory agreement of the results of these tests and determinations is evident. It will be seen that sulfur was found to be absent from all coins struck before the beginning of the second century A.D., and that it was present in all but one of the coins struck in this century. However, this is the earliest second century coin investigated. Sulfur was found to be present in another coin of the same emperor struck a few years later, but the proportion is the lowest that was found in any of the coins. It will be seen that the latest coins contained the highest proportions of sulfur. Though the number of coins investigated is perhaps too few to warrant final detailed conclusions, the pattern of the results obtained from these representative examples is so definite that some valid general conclusions seem possible.

The only likely sources of sulfur in Roman coinage brass are the sulfide ores of copper, zinc, or both. Certain considerations indicate, however, that the principal or sole source was a sulfide ore or ores of zinc. Sulfur has not been found to occur except in traces in Roman copper coins, even in those of the second

TABLE 1

Results chronologically arranged

Emperor	Date	Sample A Sulfur, %	Sample B Sulfur, %
Augustus	22 B.C.	none	none
Tiberius	22– 23 A.D.	none	none
Caligula	37– 38 " "	none	none
"	39– 40 " "	none	——
"	39– 40 " "	none	none
Claudius	41 " "	none	none
"	41 " "	none	none
Nero	64– 66 " "	none	none
Nerva	96– 98 " "	none	——
Trajan	112–114 " "	none	——
"	116–117 " "	0.08	——
Antonius Pius	141 " "	0.12	0.13
" "	154–155 " "	0.17	——
" "	154–155 " "	0.21	——
Marcus Aurelius	161–162 " "	0.17	——
" "	162–163 " "	0.28	0.28
Commodus	179 " "	0.31	0.33

century A.D., which indicates that the copper used in the manufacture of Roman coinage was obtained from oxidized ores such as cuprite or malachite. Since metallic zinc was unknown to the Romans or perhaps isolated rarely only by accident, Roman brass must have been manufactured by the cementation process, that is by stirring a mixture of zinc ore and some reducing agent, probably charcoal, into molten copper. If an oxidized ore was used, such as the carbonate, smithsonite, then the resulting brass would be free from sulfur, but if a sulfide ore, such as sphalerite, was used either alone or in admixture with an oxidized ore, then the brass would contain more or less sulfur. The above analytical results therefore indicate that only an oxidized zinc ore, probably the carbonate, was used in the manufacture of Roman coinage brass prior to about the beginning of the second century A.D., and that a sulfide ore, probably sphalerite, was admixed with the oxidized ore in increasing proportion during this century. This order of the usage of the two types of ores is what might be expected to occur generally in

the exploitation of ore bodies by ancient miners and metallurgists. The first ores used would be the more easily obtained and smelted oxidized ores near the surface of deposits, and only later would use be made of the deeper and less easily smelted sulfide ores. The fact that the percentage of zinc in Roman coinage brass decreases rapidly from about the beginning of the second century A.D. indicates either a progressive depletion of the known zinc ore deposits or a progressive depletion of the type of ore in these deposits that could be successfully smelted by the Romans. Furthermore, the fact that Roman coinage in brass ceased entirely near the end of this century indicates either the exhaustion of the known zinc ore deposits or the exhaustion of the type of ore that could be successfully smelted.

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Multiple Purpose River Development, Studies in Applied Economic Analysis. *John V. Krutilla and Otto Eckstein.* The Johns Hopkins Press, Baltimore. 1958. 301 pp. $4.50.

Krutilla and Eckstein have made one of the first attempts to analyze economically the problems of multiple purpose River development. They have tried to determine the economic efficiency of alternate plans for multiple purpose River development, and the redistribution of income accruing to members of society on a regional basis resulting from these plans.

The book is divided into two parts; the first part treats the concepts and methods of economic analysis and the second part deals with the application of the derived concepts and methods to three selected cases. In Part One, the authors set up the framework for analysis by introducing the reader to the concept of the competitive model, as an illustration of the operation of the market mechanism. The competitive model fails to take into consideration the satisfaction of group wants, direct interdependence and indivisibility of production, all of which must be considered in the water resources field. These features defy traditional methods of market analysis.

Multiple purpose river developments within a river system are generally undertaken by private interests or by a public agency or a combination of the two. The economic efficiency of the individual developer is based on the cost to each developmental unit to develop the same project, and the benefits that accrue to the purchasers of water resource derivatives result from differences in development costs. It has been found that the efficiency of the developer varies with the nature of the system to be developed. In comparing the cost of development of public and private developers the difference between opportunity cost and interest rates are a prime concern. These differences receive a thorough treatment in Chapter Four.

The cases selected for analysis in the second part of the book are: (1) The Hell's Canyon Project; (2) The Alabama-Coosa System; and (3) The Willamette Project. The efficiency of alternative plans is determined in the case of the first two projects, whereas an analysis of the redistribution of income applies to the third project.

This approach to the problem is unique in that it does not undertake to make value judgments or ethical decisions, but indicates only the more efficient of the alternative plans for the development of water resources based on economic analysis. This type of study is probably the beginning of a trend in natural resource-use analysis. But, such analyses will be of little value unless they are supported by the political process.

The market for this book will probably be limited to the small number of interested persons in this particular area of resource analysis. The substitution of the theoretical approach for the practical approach may not be readily accepted by geographer-conservationists.

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THE ORIGINAL VEGETATION OF VAN WERT COUNTY, OHIO

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INTRODUCTION

Ohio is an area where profound changes have taken place since the coming of the first settlers. This is true for all of Ohio but perhaps most strikingly so in the northwestern portion where this study was conducted. Many parts of the environment are involved, but clearing of the forest and drainage of the land have, perhaps, wrought the most drastic changes. According to Diller (1944), less than four percent of the land in the county remains in forest and this percentage continually declines. Those remnants of woodland which still remain are greatly different from the original forest and they continue to change. Disease has nearly exterminated the American elm. Grazing is causing a rapid deterioration of existing mature trees and the complete elimination of reproduction and the understory. Assuming that management does not change, within a few decades there may be almost no timbered tracts remaining. It seems desirable to record what information can be gathered while it is still available. The work reported here is a portion of a broader study dealing with the history of the natural resources of Van Wert County, Ohio. Van Wert County is particularly interesting, first because it is part of an area which was the last in the state to be settled and developed for agriculture. The changes, therefore, are relatively recent. Secondly, it is an intensively farmed region and, therefore, the magnitude of the change is great.

Over half of the land in the county was cleared for agriculture during the decade between 1870 and 1880. The field work for this study was done during the mid '40's. At that time a number of residents were found who had lived in the county prior to 1870 and who could recall early conditions and date changes with a fair degree of accuracy. These were most helpful.

LOCATION AND DESCRIPTION OF THE AREA

Van Wert County, Ohio, is in extreme western Ohio, adjacent to Indiana and about 50 miles south of the Ohio-Michigan line. The entire area of 405 square miles is drained by tributaries of the Maumee River, which empties into Lake Erie at Toledo slightly more than 70 miles to the northeast. Less than one-tenth of the county, comprising most of Willshire Township and small parts of Harrison and Liberty townships, is drained by the St. Mary's River and its tributaries. The remainder is drained by northeast-flowing tributaries of the Auglaize.

For the most part, the topography of the county is relatively flat. The only surface features of any prominence are the glacial Lake Maumee beach ridge and the Fort Wayne moraine. The moraine, with its more rolling terrain, lies across the southern tip of Jenning Township, the southwestern corner of Liberty Township, across Willshire Township and the southwestern corner of Harrison Township. Lake Maumee existed and the beach ridges were formed at a stage in the recession of the late Wisconsin ice sheet. The principal ridge lies across Washington, Ridge, Pleasant, the southwest corner of Union and central Tully Townships. At some places smaller secondary ridges are evident north or south of, and parallel to, the main ridge.

The soils of the county belong to two general groups: the lacustrine or glacial lake deposits north of the beach ridge, and Mississippi Valley till plain soils of the remainder of the county. These latter are mostly gray-brown podzolic soils of

the Miami Catena. A number of scattered prairie areas were present and at least some of those contained deposits of peat (Dachnowski, 1912). These were shallow deposits and have been burned and cultivated until little evidence of peaty material remains. The smaller ones have completely disappeared.

Van Wert County was originally surveyed in 1819. It was a swampy, heavily timbered area offering scant attraction to the settlers who followed the higher beach ridge across it to drier territories to the westward. The county is a portion of that part of northwestern Ohio which is called "The Black Swamp." Actually, only the lake plain was a part of the true Maumee Swamp, but the whole county was, for the most part, poorly drained. The channels of the small streams and even some of fair size were not well defined. Often they were merely sluggish currents flowing through broad willow swamps. The waters which rose after heavy rains did not recede for weeks. Water stood in woodland pools during most of the year. The county was mostly forested but in the shallow depression between the old lake beach ridge and the Fort Wayne moraine, a number of swales or wet prairies were found. Several of these were 2,000 acres or more in size. The total area of these treeless portions exceeded 12,000 acres.

METHODS

In preparing the present report, the original survey records in the office of the County Engineer were used in the manner described by Sears (1921). Witness trees at section and quarter-section corners were plotted on base maps and the description of timber and land along the section lines was carefully noted.

Numerous woodlots in every portion of the county were visited to check the composition of present-day forests against the original descriptions. As might be expected, the present-day forests are mostly quite different from those originally present. Due to drainage and the selection of certain species for cutting, new species have gained dominance and others have nearly, or in some cases, completely disappeared. Figure 1 is a map of the original vegetation based on data from the original land survey records and on notes compiled from field work in the county. Following are descriptions of the timber stands in the various forest types indicated on the map.

LAKE PLAIN FOREST

The lake plain area was covered by a phase of the elm, ash, maple, swamp forest in which maple was a minor component and beech, hickory, and basswood were prominent. According to a tally of witness trees, black ash (*Fraxinus nigra*) and white ash (*F. americana*) together made up more than 30 percent of the stand and elm (largely *Ulmus americana*) about half that amount. Beech (*Fagus grandifolia*) made up about 16 percent, shagbark hickory (*Carya ovata*) and big shellbark hickory (*C. laciniosa*) about 12 percent, and basswood (*Tilia americana*) about 10 percent. The remaining 17 percent was comprised of a variety of species in which oaks made up more than half. These oaks included Shumard's oak (*Quercus Shumardii*), white oak (*Q. alba*), bur oak (*Q. macrocarpa*), chinquapin oak (*Q. Muehlenbergii*), swamp white oak (*Q. bicolor*), and pin oak (*Q. pallustris*). Other species included silver maple (*Acer saccharinum*), sycamore (*Platanus occidentalis*), and cottonwood (*Populus deltoides*). Spicebush (*Benzoin aestivale*) and prickly ash (*Xanthoxylum americanum*) were most prominent in the undergrowth.

The land adjacent to the numerous streams where drainage was somewhat better supported a larger proportion of trees characteristic of less hydrophytic sites. These included beech, basswood, white oak, and sugar maple (*Acer saccharum*). From central Union Township to the north and west the drainage was exceedingly poor, and cottonwood, sycamore, and black ash were more prominent.

Adjacent to the Bear Swamp in northern Tully Township was an almost pure stand of black ash.

The woodlots now found in this area appear to approach the bur oak-big shellbark hickory transition (Sampson, 1930). Bur oak makes up about one-third of the stand. Ash and elm are both about as prominent as hickory and all occur about half as frequently as bur oak. White ash is infrequent, most ashes being green ash (*Fraxinus lanceolata*) or black ash. Other prominent species are Shumard's oak, swamp white oak, and basswood.

Present woodlots are so scattered and the composition varies so greatly, that it is necessary to generalize rather broadly in this case.

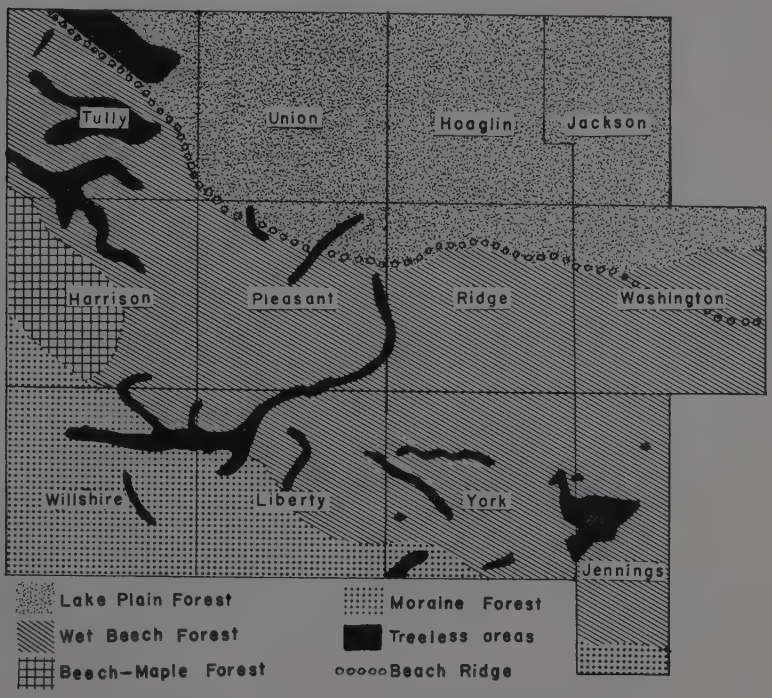

FIGURE 1. Original Vegetation of Van Wert County.

WET BEECH FOREST

That part of the county which lies between the Lake Maumee beach ridge and the Fort Wayne moraine, although quite flat, had better drainage than the lake plain. This was reflected in the forest which is probably best described by the name "wet beech." It consisted of essentially the same species as the lake plain forest, but in different proportions. A tally of witness trees in this area indicated that beech made up nearly 47 percent of the stand on the average. The ashes made up more than 18 percent, elm nearly 8 percent, and hickory between 6 and 7 percent. The remaining 20 percent included about the same minor species as were found in the lake plain and here, too, the various oaks made up about half of the total.

Microrelief, as indicated by the complex soil pattern in this area, was also reflected in the forest cover. The areas with best drainage supported some white oak and sugar maple, and down the scale through beech and basswood, elm, and white ash to swamp white oak, pin oak, black ash, and silver maple in the lower spots.

The present-day secondary forests are singularly lacking in beech, at least as compared with its former abundance. The small size of most present-day woodlots and the complexity of the soil pattern make generalizations difficult. In general, however, the more poorly drained woodlots are much like those in the lake plain area. The dominant species are bur oak and big shellbark hickory. In some of the lowest spots swamp white oak, pin oak, or silver maple is predominant. On sites with slightly better drainage an association of Shumard's oak, chinquapin oak and bur oak, with shagbark, shellbark, and bitternut hickories is found. This association is prevalent in the area.

FOREST OF THE FORT WAYNE MORAINE

In this area of more rolling topography and better drainage a third kind of forest was found. This was a transition between swamp forest and oak-hickory forest, in which red and white oaks and hickory covered the better drained ridges. Beech was the principal species on the intermediate slopes and the ash-elm swamp forest association occupied the poorly drained depressions. Over the entire area red, Shumard's, and white oaks made up more than one-third of the stand, beech made up over one-fourth, and hickory over one-fifth of the stand. Ash and elm made up about one-tenth of the stand, with ash being a little more prevalent than elm. Other species present in smaller numbers were basswood, sugar maple, bur and swamp white oaks, and scattered individuals of a number of other species.

That part of the moraine which is included in the southern part of Jennings Township was described in the original survey as being covered with scrubby red and white oak timber, and nearly all of the witness trees were of these species. The surveyor in his notes described the area and remarked that there appeared to have been a hurricane there. Quaking aspen (*Populus tremuloides*) was prominent.

In this morainal area, in addition to the spicebush and prickly ash undergrowth, hazelnut (*Corylus americana*) was frequently mentioned.

In the present-day secondary forests, most species have not changed greatly in relative dominance. Now red and white oaks make up a little less than one-third of the stand, and hickories, still about one-fifth. Sugar maple has greatly increased and, in the area checked, made up more than 17 percent of the stand, while beech occurs in very small numbers. Ash and elm in the area checked were a little more abundant than the witness tree tally indicates was originally true.

In this area Shumard's oak, which occurs almost to the exclusion of red oak in the lake plain and wet beech area, is largely replaced by this latter species. The red oak which apparently was only a little more abundant than white oak originally is now at least three times as numerous as that species. Shumard's oak was not recognized as a separate species or at least not correctly identified by the early surveyor who apparently listed it as red or black oak.

BEECH-MAPLE FOREST

An area in western Harrison Township, as indicated on the map, was covered by what can probably best be described as a wet phase of the beech-maple forest. Beech made up about one-fourth of the stand and sugar maple about half of that proportion. Ash made up about 18 percent, and white oak about 11 percent. Other prominent species were hickory, basswood, elm, and tulip tree (*Liriodendron tulipifera*). This last species was not found, except as lone individuals, in any other area of the county. Figure 2 shows the distribution of the tulip trees mentioned in the original land survey. Few were recorded outside of the area

here discussed. For the most part these records appear to be confined to the divide between the St. Mary's and the Auglaize watersheds. The area which was forested as described above corresponds fairly well with the soils area mapped as predominantly Crosby silty clay loam.

The woodlots now present contain considerable white oak. Beech is much less common than originally. Red maple (*Acer rubrum*) is fairly common and is found sparingly in only a few other areas. Flowering dogwood (*Cornus florida*) is more common here than elsewhere in the county.

TREELESS AREAS

The 12,000 acres of treeless areas were covered by a variety of shrubby and herbaceous vegetation. Willows (*Salix*) were the dominant shrubs which bordered

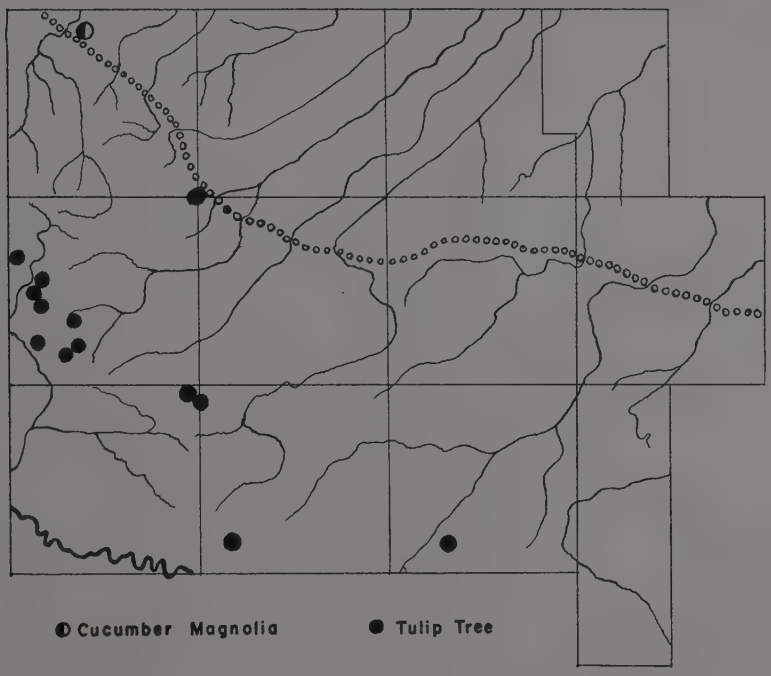

FIGURE 2. Distribution of Tulip Tree and Cucumber Magnolia.

nearly all such areas and quaking aspen was also common. Wild spirea (*Spirea alba*) can still be found in the vicinity formerly covered by the "Twenty-seven Mile Prairie" in Willshire and Harrison Townships. Buttonbush (*Cephalanthus occidentalis*) and panicled dogwood (*Cornus racemosa*) were common. Several of the areas were reported to have been covered with "a tall prairie grass' which was probably Spartina or cordgrass. A clump of this was found growing along a road in central Liberty Township. Certainly large areas were covered with sedges and large portions of some of them were muck land with bog vegetation. These areas have been drained and have been so intensively cultivated that scarcely a vestige of their original cover remains. No adequate descriptions have been

located so it is impossible to give more detailed information regarding the original condition of these "prairies."

BEACH RIDGES

The Lake Maumee beach ridge had a type of vegetation different from that of the lands adjacent to it. The name "Sugar Ridge" which the early settlers applied to it indicates that sugar maple must have been common. The Indians had sugar camps along the ridge before the first settlers came. Other trees which are known to have been common are: black walnut (*Juglans nigra*), butternut (*Juglans cinerea*), red elm (*Ulmus fulva*), beech, red oak, and chinquapin oak. All are species characteristic of moist, well-drained sites. On the ridge in the extreme northwest corner of the county the early surveyors recorded a cucumber tree (*Magnolia acuminata*) 15 in. in diameter. This locality is far to the west of its normal range. It is not a species that would be readily confused, and the sandy soils of the Lake Maumee beach ridge, unlike all other soils in this part of the state, might be favorable for its growth. It seems quite probable that at one time it may have occurred occasionally along this narrow strip of sandy soil, even as far west as the state line. No adequate description of the ridge forest has been located and no remnants are now to be found.

SUMMARY

This paper documents the information that is available concerning the nature and distribution of the original forests of Van Wert County, Ohio, and notes changes in the remnants still present. The information presented is based upon data collected from the original land surveys of the county, from field observation of remaining forested tracts and, in some small degree, upon the recollection of a number of persons old enough to remember their youth in the unsettled swamp country. The future of woodland in this region is not encouraging. Grazing and disease are rapidly destroying existing woodlots. The time may not be far distant when nothing remains to even hint at the nature of the swampy forest which appeared so inhospitable to the pioneers who pushed westward along the ridges.

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This notice calls attention to the availability of a new edition of an old standby. Its contents have been revised and expanded, and the issuance of the second book as a supplement to the first is evidence of the limits of expandibility.

THOMAS H. LANGLOIS

SONGS OF FINCHES (FRINGILLIDAE) OF EASTERN NORTH AMERICA

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In the preparation of a phonograph record of finch songs (Borror and Gunn, 1960), I had an opportunity to study over 1800 recordings of eastern finches, from 21 states of the United States and 5 provinces of Canada. Many of the songs in these recordings were analyzed by means of a Vibralyzer sound spectrograph (Borror and Reese, 1953), and the graphs obtained reveal many details of the songs and their variation. The purpose of this paper is to present accounts of the songs of 43 species of eastern fringillids, based on a study of these recordings. Brief descriptions of these songs are given in many bird guides (e.g., Peterson, 1947; Saunders, 1951a); references to papers on the songs of individual species are cited in the following accounts.

The majority of the recordings studied (table 1) were made by myself, and are in the collection of recorded animal sounds of the Department of Zoology and Entomology, The Ohio State University; additional recordings were loaned by Dr. William W. H. Gunn and Dr. J. Bruce Falls of Toronto, and Dr. P. P. Kellogg of Cornell University.

The term "song," as used here, refers to the vocalizations, usually uttered only by the male and usually more complex in character than the bird's various call notes, which appear to function in advertising the presence of the male, in attracting a female, or in repelling other males of the same species or all of these. The descriptions in this paper refer principally to what is commonly called the "advertising song," which in many species serves the other functions as well.

There is a great deal of variation in finch songs; the songs of different species are often quite different, and there is frequently considerable variation in the songs of a given species. In some species the songs of a given bird are essentially alike, while those of different birds often differ; in other species each bird may sing songs of two or more different patterns. The intraspecific variation in each species is outlined briefly in the following accounts. The pitch range in the songs of each species is summarized in table 1.

The song patterns of many finches are not perfected until the birds reach the nesting grounds, and the songs of birds in migration are often a little different (more variable, with the patterns less well defined) from those of birds on the nesting grounds. The following accounts apply in most cases to the songs of birds on the nesting grounds.

References in the list below to side and band number refer to the location of the songs on the phonograph record (Borror and Gunn, 1960). References such as "(S–8)" in the figure legends indicate the song on the record that is graphed; S–8 would indicate that the song graphed was the eighth song of that species on the record.

The songs of eastern fringillids may be arranged, on the basis of their pattern and quality, in nine groups, as follows:

Group 1. Songs composed of one or more series of clear whistled notes or phrases (side 1, bands 1 and 2).

1. Cardinal (*Richmondena cardinalis*)
2. Harris' Sparrow (*Zonotrichia querula*)
3. White-throated Sparrow (*Zonotrichia albicollis*)
4. Field Sparrow (*Spizella pusilla*)

TABLE 1

Summary of recordings studied and pitch range in Fringillid songs

Group	Species	Recordings Studied No.	Source Localities	Pitch Range (in cycles/sec)
1	Cardinal	156	Ala., Fla., Ga., Ky., Ohio, Ont., Pa., Tex., W. Va.	1500–4500
	Harris' Sparrow	3	Man.	2500–4400
	White-throated Sparrow	172	Man., Mass., Me., N. B., N. C., N. Y., Ohio, Ont., Que., Vt.	1500–6600
	Field Sparrow	89	Ky., Ohio, Ont., Pa.	2100–5000
2	White-crowned Sparrow	19	Man., Ohio, Ont.	2600–7200
	Tree Sparrow	13	Man., Ohio	3000–8000
	Smith's Longspur	1	Man.	3300–6200
	Fox Sparrow	30	Man., Ohio, Ont.	3000–5000
3	Rose-breasted Grosbeak	31	Me., Mich., Ohio, Ont.	3000–9000
	Pine Grosbeak	2	Man., N. B.	2300–4600
	Purple Finch	43	Man., Me., Ohio, Ont.	2000–8000
	Painted Bunting	1	S. C.	3000–6000
4	Blue Grosbeak	4	Ohio	2300–6700
	Indigo Bunting	44	Ky., Me., Mich., Ohio, Ont., Tenn.	2200–9000
	Dickcissel	18	Ind., Ky., Ohio, Wisc.	2500–9000
5	Slate-colored Junco	46	Man., Me., Mich., Ohio, Ont., Que.	2500–7000
	Chipping Sparrow	111	Man., Me., Mich., N. C., Ohio, Ont., Pa., W. Va.	2000–9000
	Swamp Sparrow	36	Me., Ohio, Ont.	2600–8000
6	Rufous-sided Towhee	183	Fla., Me., Mich., N. C., Ohio, Ont., W. Va.	2000–6000
	Bachman's Sparrow	17	Fla., Ohio	1500–10800
7	Vesper Sparrow	36	Mich., Ohio, Ont.	2200–9000
	Lincoln's Sparrow	12	Ont., Wyo.	1700–8500
	Lark Bunting	3	Sask., Wyo.	1500–8000
	Lark Sparrow	9	Ohio, Tex.	1300–10000
	White-winged Crossbill	9	Me.	3000–6000
	Common Redpoll	4	Man., Ont.	3000–6000
	American Goldfinch	37	Me., N. C., Ohio	2000–8000
	Pine Siskin	2	Ohio	2000–8000
8	Clay-colored Sparrow	7	Mich., Ont.	2500–8500
	Le Conte's Sparrow	4	Man.	6000–10000
	Grasshopper Sparrow	18	Man., N. D., Ohio, Ont.	4200–10000
	Sharp-tailed Sparrow	12	Man., Me.	3000–7500
	Seaside Sparrow	9	Fla., N. J.	1500–7000
	Savannah Sparrow	24	Man., Me., Ohio, Ont.	2600–9500
	Baird's Sparrow	6	Man.	4000–8000
9	Song Sparrow	583	Me., Ohio, Ont., W. Va.	1800–9000
	Lapland Longspur	2	Man.	1800–7800
	Chestnut-collared Longspur	4	Man.	2300–6500
	McCown's Longspur	1	Sask.	1700–6000
	Henslow's Sparrow	9	Ohio	3100–10200
	Evening Grosbeak	7	N. B., Ont., Pa.	2500–4000
	Red Crossbill	7	Me.	3000–6000
	Snow Bunting	2	Man.	2500–6000
	Total	1826	21 states, 5 provinces	1300–10800

Group 2. Songs of clear whistled notes, with a few short buzzes or trills or both (side 1, band 3).
5. White-crowned Sparrow (*Zonotrichia leucophrys*)
6. Tree Sparrow (*Spizella arborea*)
7. Smith's Longspur ((*Calcarius pictus*)
8. Fox Sparrow (*Passerella iliaca*)

Group 3. Songs a series of warbled or wavering phrases, successive phrases usually different (side 1, band 4).
9. Rose-breasted Grosbeak (*Pheucticus ludovicianus*)
10. Pine Grosbeak (*Pinicola enucleator*)
11. Purple Finch (*Carpodacus purpureus*)
12. Painted Bunting (*Passerina ciris*)

Group 4. Songs a series of loud phrases, successive phrases often similar (side 1, band 5).
13. Blue Grosbeak (*Guiraca caerulea*)
14. Indigo Bunting (*Passerina cyanea*)
15. Dickcissel (*Spiza americana*)

Group 5. Songs a simple trill (side 1, band 6).
16. Slate-colored Junco (*Junco hyemalis*)
17. Chipping Sparrow (*Spizella passerina*)
18. Swamp Sparrow (*Melospiza georgiana*)

Group 6. Songs of 1 to 4 introductory notes followed by a trill (side 1, band 7).
19. Rufous-sided Towhee (*Pipilo erythrophthalmus*)
20. Bachman's Sparrow (*Aimophila aestivalis*)

Group 7. Songs consisting principally of two or more trills (side 2, bands 1 and 2).
21. Vesper Sparrow (*Pooecetes gramineus*)
22. Lincoln's Sparrow (*Melospiza lincolnii*)
23. Lark Bunting (*Calamospiza melanocorys*)
24. Lark Sparrow (*Chondestes grammacus*)
25. White-winged Crossbill (*Loxia leucoptera*)
26. Common Redpoll (*Acanthis flammea*)
27. American Goldfinch (*Spinus tristis*)
28. Pine Siskin (*Spinus pinus*)

Group 8. Buzzy songs (side 2, bands 3 and 4).
29. Clay-colored Sparrow (*Spizella pallida*)
30. Le Conte's Sparrow (*Passerherbulus caudacutus*)
31. Grasshopper Sparrow (*Ammodramus savannarum*)
32. Sharp-tailed Sparrow (*Ammospiza caudacuta*)
33. Seaside Sparrow (*Ammospiza maritima*)
34. Savannah Sparrow (*Passerculus sandwichensis*)
35. Baird's Sparrow (*Ammodramus bairdii*)

Group 9. Miscellaneous songs, not readily classifiable into any of the above groups (side 2, bands 5–7).
36. Song Sparrow (*Melospiza melodia*)
37. Lapland Longspur (*Calcarius lapponicus*)
38. Chestnut-collared Longspur (*Calcarius ornatus*)
39. McCown's Longspur (*Rhynchophanes mccownii*)
40. Henslow's Sparrow (*Passerherbulus henslowii*)
41. Evening Grosbeak (*Hesperiphona vespertina*)
42. Red Crossbill (*Loxia curvirostra*)
43. Snow Bunting (*Plectrophenax nivalis*)

1. *Cardinal.*—The song consists of a series of 1 to 43 loud, clear, whistled phrases uttered 1 to 9 per sec; the first phrase or two are often uttered a little more slowly than the following phrases. Most songs are 2 to 4 sec in length. The phrases contain 1 to 3 (rarely 4 to 5) notes, which are nearly all slurred, some

very abruptly. The song may be 1-parted (all the phrases alike and, except for the first phrase or two, uttered at a uniform rate) (fig. 1), or it may contain up to 5 parts; most songs with 2 or 3 parts have different phrases in the different parts. Some songs with 2 or more parts have the phrases in the second or third part very similar to those in the preceding part but uttered at a different rate (usually more slowly) or at a different (usually lower) pitch. The songs are sometimes followed by a weak buzzy trill (short notes uttered 25 to 30 per sec) that sounds a little like the trill of a red squirrel. Each bird has a vocabulary of several different phrases, which are combined to produce a number of different song patterns (with 1 to 3 phrase types per pattern). Different birds, particularly those in different areas, usually have different phrases in their vocabulary, though some phrases may be sung by birds in widely separated areas (Borror, 1961).

2. *Harris' Sparrow.*—The song is 1 to 3 clear whistled notes that are steady in pitch. The first note (*the* note in 1-note songs) is about 1 sec in length; the other notes are about half as long. All the notes of the song are on the same pitch, but a given bird may sing songs at 2 or 3 different pitches. The songs of different birds are very similar.

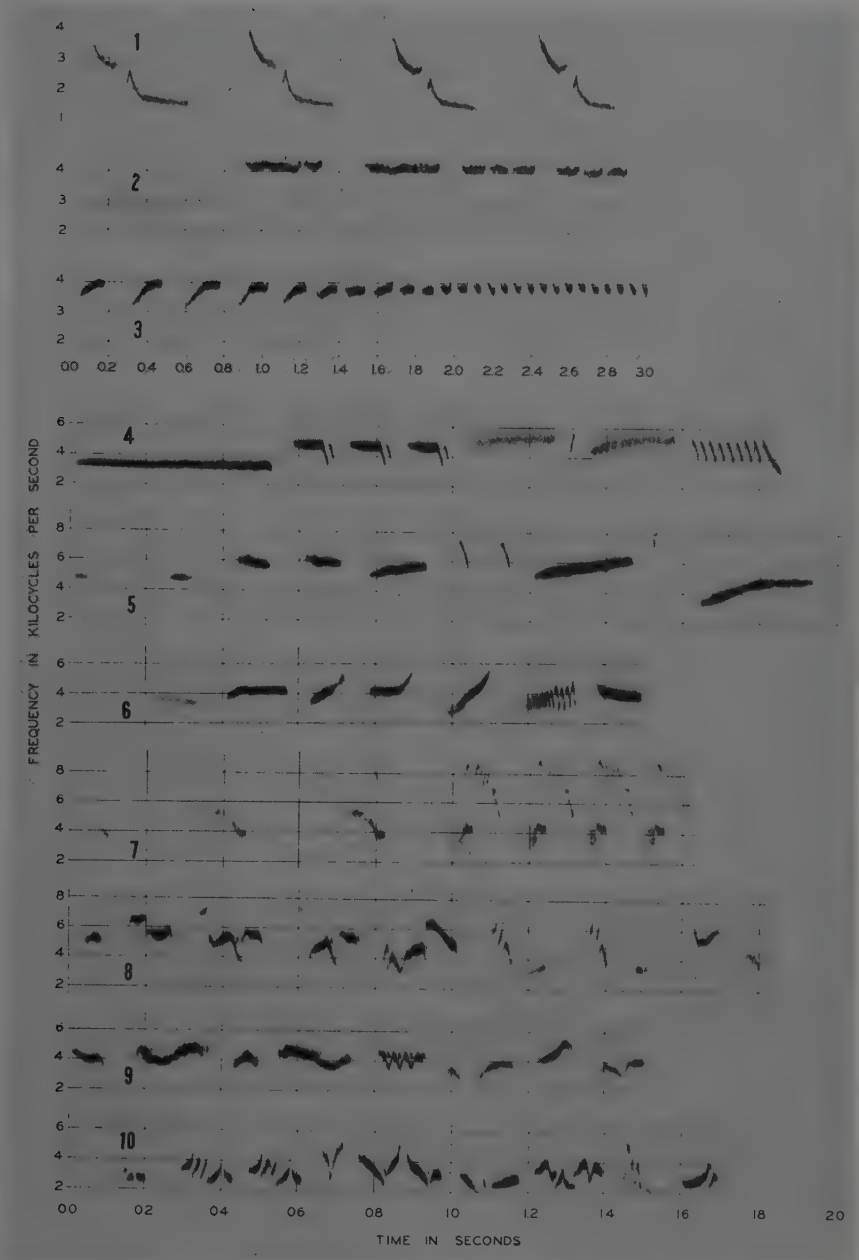
3. *White-throated Sparrow.*—The song is a series of clear whistled notes, most of them steady in pitch; it usually begins with 1 or more relatively long notes, and ends in triplets (groups of 3 notes uttered in rapid succession). There is nearly always at least one pitch change in the song, usually after the first or second note, and there are 2 or 3 pitch changes in some songs. Many songs have 1 note (usually the third) beginning with an abrupt up-slur. The songs of a given bird are generally alike in the way the pitch changes through the song, but may vary in length; the songs of different birds often have different pitch changes. The most common song pattern in this species, occurring throughout its range, begins with a low note, with the rest of the song on a higher pitch: *tooo tititi twee tititi tititi*. Many eastern songs have a very short note (0.02 to 0.04 sec in length) following the second note of the song (fig. 2): *tooo titi p-tee tititi tititi*. Many songs in the midwest begin with 2 long high notes, with the remaining notes at a lower pitch: *teee teee tooo tototo tototo*. Some songs in the western part of the bird's range begin with a rapid series of short notes followed by a longer note, all on the same pitch, with the remaining notes at a higher pitch: *tototototototototo tooo teee tititi tititi*. Most song patterns in this species begin with a long low note, with the second note higher in pitch; the remaining notes may be the same pitch as the second, or some may be at a different pitch.

4. *Field Sparrow.*—The song is a series of 5 to 39 clear whistled notes, with the introductory notes longer and uttered more slowly; the song usually ends in a trill. The transition from slow introductory to fast final notes may be abrupt or gradual. The notes are uttered 2 to 6 per sec at the beginning of the song, and 6 to 48 per sec at the end. The introductory notes may be steady in pitch, slightly up-slurred (fig. 3), down-slurred, or down-slurred and then up-slurred; the final notes are usually abruptly down-slurred. The pitch trend through the

EXPLANATION OF FIGURES

FIGURES 1–10. Sound spectrographs of finch songs.

1. Cardinal. Franklin Co., Ohio, May 16, 1956 (OSU, 1880–4) (S–8).
2. White-throated Sparrow. Lincoln Co., Maine, June 15, 1957 (OSU, 2846–4) (S–7).
3. Field Sparrow. Franklin Co., Ohio, April 19, 1958 (OSU, 3230–3) (S–4).
4. White-crowned Sparrow. Moosonee, Ontario, May 29, 1958 (Gunn, C5–1) (S–2).
5. Tree Sparrow. Churchill, Manitoba, June 14, 1958 (Gunn, C2–4) (S–10).
6. Smith's Longspur. Churchill, Manitoba, June 22, 1958 (Gunn, C1–3) (S–3).
7. Dickcissel. Shelby Co., Kentucky, June 16, 1954 (OSU, 1239–6) (S–4).
8. Indigo Bunting. Franklin Co., Ohio, May 16, 1957 (OSU, 2660–5) (S–1).
9. Painted Bunting. Charleston, South Carolina, May 6, 1957 (Gunn, C1–8) (S–8).
10. Purple Finch. Lincoln Co., Maine, June 21, 1957 (OSU, 2875–2) (S–2).


1
2
3
4
5
6
7
8
9
10
FREQUENCY IN KILOCYCLES PER SECOND
00 02 04 06 08 10 12 14 16 18 20 22 24 26 28 30
00 02 04 06 08 10 12 14 16 18 20
TIME IN SECONDS

song is usually steady (fig. 3), but in some songs the pitch may rise or fall slightly toward the end of the song; the pitch range in a song is always less than an octave. The songs of a given bird are generally alike except in length, but some birds may sing songs of 2 or 3 slightly different patterns; the songs of different birds are usually a little different. Occasional birds have songs that are somewhat atypical for the species (Saunders, 1922).

5. *White-crowned Sparrow.*—The song usually begins with 1 to 3 clear whistled notes that are steady in pitch, and ends with three buzzy notes, the last lower in pitch than the two preceding (fig. 4). The first note is about 0.5 sec in length; if there are 2 or 3 similar introductory notes the second and third are a little shorter. The final buzzy notes are uttered 3 to 4 per sec. Sometimes there are short clear notes or 2-note phrases in the middle of the song (fig. 4), and sometimes the second or third note of the song is slurred. One or two of the final buzzes (except the last) may begin with a short sharp note or be slightly up-slurred or both (fig. 4). Some songs end in a low trill rather than a low buzzy note. The songs of a given bird are usually very similar, but those of different birds often differ slightly.

6. *Tree Sparrow.*—The song is a series of clear high-pitched whistled notes; most notes are uttered 5 to 6 per sec, and the song is 2 to 2.5 sec in length. Some songs (fig. 5) begin with steady notes and end in slurred notes, with the pitch falling a little toward the end of the song; other songs (e.g., some from Ohio) have most of the notes slurred, some very abruptly. The song does not contain a trill, and contains buzzy notes only rarely. The songs of a given bird on the nesting grounds are generally of the same pattern but may vary in length, and the songs of different birds are usually a little different. Many songs, particularly of migrating birds, are a little like those of a fox sparrow, but the notes are usually shorter and higher-pitched, and the song seldom contains buzzy notes (which occur in most fox sparrow songs).

7. *Smith's Longspur.*—Only one recording of this species was studied; the songs were all of the same pattern and contained 6 to 8 notes (fig. 6). The next to the last note was buzzy, and the rest were clear whistles; the first note or two of the song were rather weak. The song might be paraphrased *ta ta tee twe twe twee werr-tee.*

8. *Fox Sparrow.*—The song is a series of loud whistled notes, most of them slurred, and it commonly ends in a buzzy note, a sharp *chuck*, or both. Most notes are uttered 3 to 5 per sec, sometimes grouped in 2- or 3-note phrases; successive notes are usually a little different. Most songs are 2 to 2.5 sec in length. The song occasionally contains buzzy notes, but only rarely contains a trill. The songs of a given bird are usually of the same pattern, but may vary in length; the songs of different birds are often a little different.

9. *Rose-breasted Grosbeak.*—The song is robinlike, but of a slightly different quality and with the phrases more run together. It contains up to 20 or more phrases uttered 1 to 2 per sec; each phrase contains 1 to 4 wavering notes. Each bird has a vocabulary of 15 or more different phrases, but these phrases are not uttered in any definite sequence; a given phrase is rarely uttered twice in succession, but may be uttered 2 or 3 times in different parts of the same song. Some songs contain relatively long slurred whistles, and the bird often utters a characteristic *quit* in or between songs. The phrases of different birds are usually a little different.

10. *Pine Grosbeak.*—The song is similar in quality to that of a purple finch, and consists of a series of 8 to 19 phrases uttered 6 to 7 per sec. Each phrase contains 1 to 3 slurred notes, and the phrases in a song are usually all different. The songs of a given bird may differ in pattern (i.e., contain different series of phrases), and the songs of a given pattern may vary in length. The songs of different birds are similar but usually contain slightly different phrases.

11. *Purple Finch.*—The song is a series of warbled phrases uttered 5 to 8

per sec (fig. 10). Most phrases contain both up- and down-slurred elements, and the slurring may be abrupt or gradual; a few phrases contain buzzy elements. The song is similar to that of a warbling vireo, but the phrases are very similar in pitch and the song lacks the rising pitch at the end characteristic of the vireo. Most phrases are sung only once in a song. The songs are generally about 2 sec in length but occasionally, especially early in the season, a song may be several seconds in length or the bird may sing almost continuously. The songs of a given bird are generally alike but may vary in length; each bird appears to utter a definite sequence of phrases, and different songs may end at different points in this sequence; where phrases are repeated, the number sung in sequence may differ in different songs. The songs of different birds are usually quite similar, particularly if the birds occur in the same area, but usually contain slightly different phrases.

12. *Painted Bunting.*—The song is somewhat similar to that of a warbling vireo, and consists of 8 to 11 phrases uttered 5 to 6 per sec (fig. 9); the song rarely ends in a high note, as do most songs of the vireo. The notes are all slurred, but the slurring is not abrupt. A bird may sing songs of 2 or more patterns, and the songs of a given pattern may differ in length. Only one recording of this species was studied, but it is probable that the phrases of different birds are a little different.

13. *Blue Grosbeak.*—The song is loud and clear and generally contains 10 to 17 phrases uttered about 5 per sec. Most phrases contain 1 or 2 notes, and both up- and down-slurred elements; some phrases are trilly or buzzy. Some phrases are sung 2 or 3 times in succession, or may appear in different parts of the same song. The songs of a given bird may vary in the number or sequence of the different phrases, and the songs of different birds usually contain slightly different phrases.

14. *Indigo Bunting.*—The song is loud, not particularly musical, and consists of a series of phrases about half of which are in twos; the phrases are uttered 3 to 9 per sec (fig. 8). The song may contain up to about two dozen phrases, but most songs contain 10 to 12 phrases. Each phrase may contain from one to several notes, and nearly all the notes are slurred, some very abruptly. A typical song might be paraphrased *tee tyu tyu swee swee chew chew chew chi chi whit.* The songs of a given bird usually vary in the number and types of phrases they contain; there is a great deal of variation in the phrases of different birds.

15. *Dickcissel.*—The song usually consists of 2 series of notes or phrases: *chup chup chup ciss-ciss-ciss-ciss* (fig. 7). The first series contains 1 to 4 phrases uttered 2.5 to 5 per sec, and the second 3 to 6 phrases uttered 6 to 7 per sec. The rate sometimes increases a little through the first series, or there may be a longer interval after the first or second phrase of the second series. Some songs are preceded by 1 to 5 short chips. The phrases are usually buzzy or contain buzzy elements; the phrases of the first series may appear 1- to 3-noted, and usually appear slurred; the phrases of the second series usually appear 2-noted, with the pitch rising or falling through the phrase and the last part of the phrase buzzy. The songs of a given bird are of one pattern (i.e., they contain the same types of phrases), but the phrases may vary in number. The songs of different birds often contain slightly different phrases; the 18 recordings studied contained 9 different song patterns.

16. *Slate-colored Junco.*—The song is a series of 12 to 39 similar phrases uttered 8 to 20 per sec (fig. 11), and is very similar to that of a chipping sparrow; most songs are 1 to 2 sec in length. The phrases contain 2 to 5 notes; most notes are slurred, sometimes abruptly but usually over less than an octave. In most songs at least one note in the phrase is either steady in pitch or is slurred only slightly, and the song is more musical than that of a chipping sparrow. A part of each phrase is buzzy in most songs. The songs of a given bird are of the same

pattern (phrase type) but may vary in length; the songs of different birds are often a little different (the 46 recordings studied contained 19 different patterns).

17. *Chipping Sparrow.*—The song is a series of 9 to 72 similar phrases uttered, 7 to 22 per sec; most songs are 2 to 3 sec in length. The phrases contain 1 to 3 notes which are abruptly slurred, sometimes over an octave or more in 0.01 to 0.05 sec. This rapid slurring over a considerable pitch range gives the song a rather dull and unmusical quality. One note in each phrase is buzzy in some songs. The songs of a given bird are of the same pattern (phrase type) but vary in length; the songs of different birds are often a little different (the 111 recordings studied contained 39 different patterns) (Brand and Axtell, 1938; Borror, 1959b).

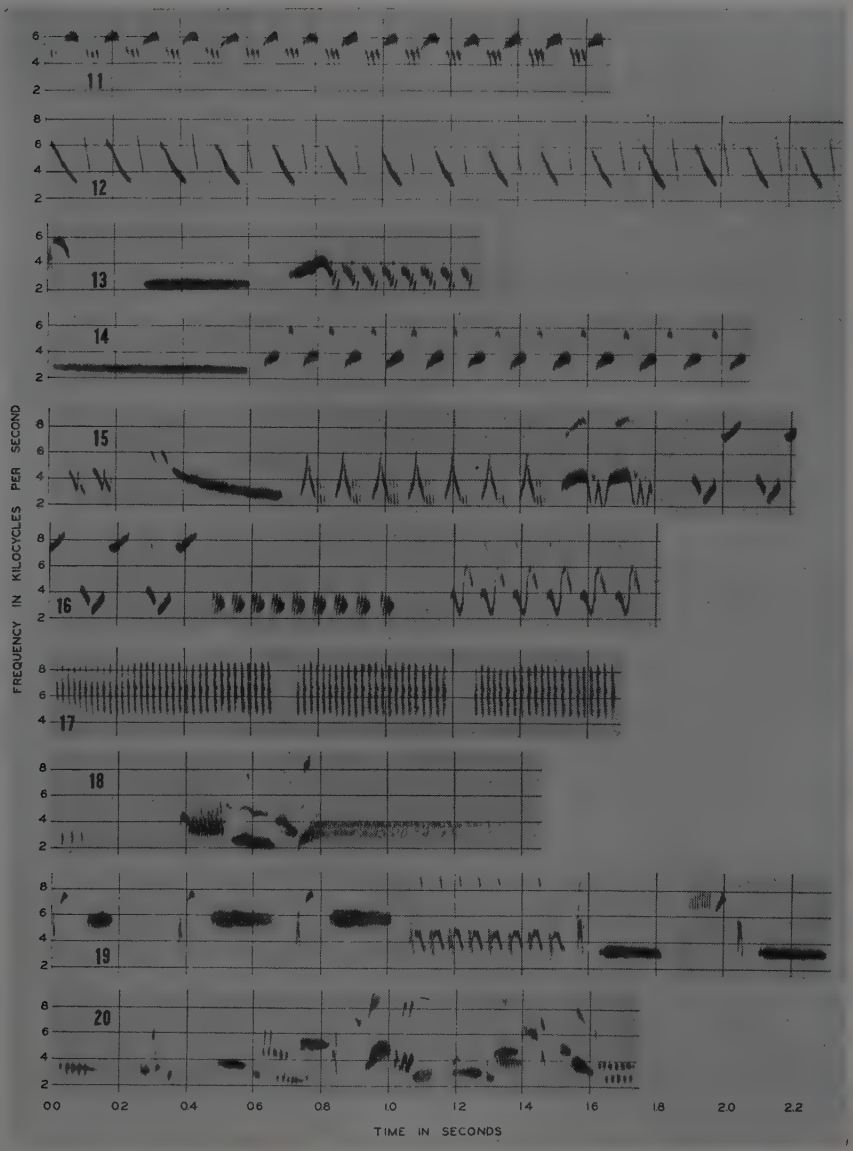
18. *Swamp Sparrow.*—The song is a series of 8 to 21 similar phrases uttered 5.6 to 8.8 per sec (fig. 12). The phrases generally appear 2-noted (the 2 notes of different pitch), but nearly always contain 3 to 4 notes. Most of the notes are slurred, some very abruptly over about an octave, giving the song a staccato quality. The song resembles a slow chipping sparrow song, but the phrases are more obviously composed of more than 1 note. The songs of a given bird are usually all of the same pattern (phrase type) but vary in length; the songs of different birds are often a little different (the 36 recordings studied contained 19 different patterns).

19. *Rufous-sided Towhee.*—The song consists of 1 to 2 (rarely 3 to 4) introductory notes followed by a trill; the trill frequently (fig. 13) begins with a note or phrase that is different from the remaining trill phrases. The introductory notes may be clear or buzzy, steady in pitch or slurred, and are uttered about 4 per sec; if the introduction contains 2 or more notes, these notes are usually different in pitch. The trill may contain up to 18 phrases uttered 5 to 35 (average, about 13) per sec. Each bird may sing songs of 3 or 4 different patterns; it usually sings one pattern for a while and then changes to another, but occasionally may sing songs of two patterns alternately. The songs of different birds are usually different; a given type of introduction of trill is frequently sung by different birds, but it is relatively uncommon for the entire song of different birds to be identical (Borror, 1959a).

20. *Bachman's Sparrow.*—The song consists of 1 or 2 introductory notes and a trill; the introductory notes are relatively long and usually steady in pitch, and the trill is a rapid series of similar phrases (fig. 14). Most songs begin with a single introductory note, either a clear whistle or a buzz; some songs begin with 2 notes, nearly always different in pitch, either 2 whistles or a buzz and a whistle. Each bird has a repertoire of two dozen or more different songs (one Ohio bird studied had 37), which differ in the character of the introduction and trill. The pitch of the introductory note(s) varies considerably in different songs. The trill contains 3 to 20 (usually 7 to 11) phrases uttered 5 to 25 (mostly 6 to 8) per sec; the phrases contain 1 to 4 notes. Some songs contain a 2-parted trill, i.e., a few phrases of one type, then a few of another type. A bird seldom sings more than 1 or 2 songs of a given pattern before changing to another. The songs

EXPLANATION OF FIGURES

FIGURES 11–20. Sound spectrographs of finch songs.

11. Slate-colored Junco. Lincoln Co., Maine, July 3, 1958 (OSU, 3567–3) (S–8).
12. Swamp Sparrow. Lincoln Co., Maine, June 25, 1959 (OSU, 4205–9) (S–1).
13. Rufous-sided Towhee. Reynoldsburg, Ohio, May 6, 1956 (OSU, 1808 2) (S 7).
14. Bachman's Sparrow. Reynoldsburg, Ohio, May 15, 1955 (OSU, 1419-9) (S-8).
15. Lark Sparrow. Adams Co., Ohio, May 12, 1958 (OSU, 3384–5) (S–1).
16. Lark Sparrow. Last part of same song shown in fig. 15 (from 2.0 sec to end).
17. Clay-colored Sparrow. York Co., Ontario, June 28, 1957 (Gunn, C3-39) (S 3).
18. Seaside Sparrow. Panacea, Florida, March 20, 1959 (OSU, 3750-25) (S-9).
19. Song Sparrow. Lincoln Co., Maine, June 21, 1956 (OSU, 2065–5) (S–11).
20. Lapland Longspur. Churchill, Manitoba, June 21, 1958 (Gunn, C5–6) (S–last).

11
12
13
14
15
16
17
18
19
20
FREQUENCY IN KILOCYCLES PER SECOND
00 02 04 06 08 10 12 14 16 18 20 22
TIME IN SECONDS

of different birds usually differ in the character of the trill phrases (Borror, 1961).

21. *Vesper Sparrow.* The song consists of 1 to 4 relatively long, steady or slightly down-slurred notes (or 2-note phrases in which one note is much longer than the other), followed by 2 to 7 groups of more rapidly uttered phrases; most songs are 2 to 4 sec in length. The introductory notes are usually of 2 types, the first one or two being weaker and lower-pitched than the rest. Each of the remaining phrase groups contains up to 10 similar phrases, and each phrase contains 1 to 4 notes; many of the notes are buzzy. The phrases are uttered 3 to 20 (average, 5.5) per sec; most phrases are uttered slowly enough to count. A typical song might be paraphrased *tyu tyu tee tee witiwitiwiti-titotito-tyu-tyu-tyu-tyu-chee-chee-chee-chee.* The songs of a given bird usually vary in the number of phrases and phrase types they contain, and often also in the sequence of the various phrase types; occasionally they may vary in the character of the introductory notes. The phrases of different birds are usually different.

22. *Lincoln's Sparrow.*—The song is somewhat similar to that of a house wren but is more musical. It consists of 4 to 9 groups of trilly or buzzy phrases, with up to 15 similar phrases per group, and with the phrases uttered 3 to 18 per sec. Most songs begin with 1 to 4 low-pitched phrases and end in weak, low-pitched, and often buzzy phrases. Many of the phrases are buzzy, and some are (or contain) clear whistles (steady in pitch or slurred). Successive phrase groups usually differ in pitch, and the pitch range in a song may be as much as 2 octaves. The songs of a given bird vary in the number of phrases in the different groups, and in the phrase types in the song (i.e., in pattern); a bird may sing songs of 3 or more patterns, usually several songs of one pattern, then several of another. The songs of different birds are usually a little different, but those of birds in the same locality usually contain similar or identical phrases.

23. *Lark Bunting.*—The song is 3 to 8 or more groups of phrases, the phrases of each group similar and uttered 3 to 20 (mostly 4 to 8) per sec. Some songs contain a buzzy note 0.5 sec or more in length, and most phrases contain at least 1 buzzy note. The buzzy notes are usually steady in pitch; the clear notes may be steady or slurred. Each phrase group may contain up to 18 phrases, but most groups contain 4 to 8 phrases. Each bird has a vocabulary of several phrase types, which are variously combined in different songs; there is no tendency for the bird to utter its different phrases in any definite sequence. The phrases of different birds are usually a little different.

24. *Lark Sparrow.*—The song is relatively loud and musical, and consists of 3 to 11 series of trills or phrase groups, each group containing up to 19 similar phrases uttered 2 to 34 (average, about 16) per sec (fig. 15, 16). Each bird has a vocabulary of 20 or more phrases, which are variously combined to produce a large number of different song patterns (one Ohio bird studied had 58). The songs have no fixed type of beginning or end, though several songs in sequence may begin with the same groups of phrases. Each phrase contains 1 to 4 notes. Most of the notes are abruptly slurred over an octave or more; many are harsh or buzzy in quality, and most songs contain at least some buzzy notes or phrases. The phrases of different birds are usually different.

25. *White-winged Crossbill.*—The song is a series of buzzy, canarylike trills, each trill consisting of a rapid series of similar phrases. The songs are 2 to 15 (most are 4 to 6) seconds in length and contain 3 to 13 trills; each trill may contain up to 35 phrases uttered 6 to 37 (mostly 10 to 16) per sec. Each phrase may contain from one to several notes, and most phrases contain buzzy elements. Each bird has a vocabulary of 15 to 20 or more different trill phrases, and these are variously combined to produce a variety of songs. Some songs contain a given type of trill in 2 different parts of the song, or 2 consecutive trills may contain essentially the same trill phrases but uttered at a slightly different rate or pitch. There is some tendency for a bird to utter its different trills in a par-

ticular sequence, but different songs are usually different, both in the types of trills they contain and in the number of phrases in each trill. The songs of different birds usually differ in the character of the trill phrases. A bird often begins a song on one perch and flies to another without interrupting the song.

26. Common Redpoll[1].—The song is a series of short trills, each trill containing 2 to 8 or more similar phrases uttered 6 to 30 (mostly 8 to 10) per sec. The phrases are rather buzzy or lisping, and the song occasionally contains slurred whines or nasal notes similar to those of the goldfinch and siskin. The trills are uttered at the rate of 1 every sec or two, and the song is long-continued. The phrases of a given bird are mostly of just 1 type but may occasionally be of 2 or 3 types, and some trills are 2-parted. The phrases of different birds are usually different.

27. *American Goldfinch.*—The song is twittery and canarylike, a series of short phrases or trills; sometimes the songs are short (1.5 to 2.5 sec in length) and separated by silent intervals of several seconds, and sometimes the song is long-continued. The phrases contain 1 to 3 notes, which may be abruptly slurred, buzzy, or may contain both buzzy and slurred elements; the song rarely contains notes that are steady in pitch. The phrases are uttered 3 to 16 per sec, and in some series often change gradually through the series from one type to another. A characteristic call, usually uttered in flight, consists of 4 (occasionally more) notes: *per-chick-tili*; all these notes are abruptly down-slurred, and the first two are a little higher in pitch than the rest; the second note is the loudest. Another characteristic call is an up-slurred or 2-parted whine; if 2-parted the first part is relatively steady in pitch and the second part is up-slurred and often wavering. The songs of a given bird often vary considerably in the number or types of phrases, or both, that they contain; the songs of different birds usually contain slightly different phrases.

28. *Pine Siskin.*—The song is somewhat similar to that of a goldfinch, but is a little softer and more nasal in quality. It consists of a series of buzzy, whiny, or warbly phrases, mostly uttered 3 to 8 per sec: a few of one type, then a few of another type, and so on. The song is long-continued, and interspersed among the short phrases are up-slurred whines and buzzes. A characteristic buzz by which this bird may often be recognized is about 1 sec in length and increases in loudness and pitch toward the end, and it usually ends in a short abrupt note.

29. *Clay-colored Sparrow.*—The song is usually a series of 1 to 6 similar high-pitched buzzes that vary in length up to about 1 sec (fig. 17); most songs are 1.5 to 2 sec in length. The buzzes consist of a series of similar phrases uttered 42 to 146 per sec; each phrase consists of 2 to 3 very abruptly slurred notes. The song sometimes consists of 11 to 13 buzzes, the first 6 or 7 of which are shorter and more rapidly uttered and contain more rapidly uttered phrases. The songs of a given bird may vary in the number of buzzes they contain, and the songs of different birds may differ in the number or character of the buzzes, or both of these.

30. *Le Conte's Sparrow.*—The song consists principally of two high-pitched buzzes that have a hissing quality; the first buzz is a little higher in pitch and about 0.5 sec in length, and the second is about 1 sec in length. The song is usually preceded by 2 to 3 very short (less than 0.005 sec in length), sharp, weak notes uttered over a space of about 0.1 sec, and there is a similar note at the end of the song. The songs of a given bird are essentially alike, and those of different birds are very similar.

31. *Grasshopper Sparrow.*—Most songs consist of 2 to 4 short, high-pitched notes followed by a long buzz that usually ends in a short high-pitched note.

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[1]The songs in the recordings studied were principally of this species, but some may have been of the Hoary Redpoll (*Acanthis hornemanni*); the songs of these two species are very similar.

The introductory notes are usually of decreasing pitch; if there are 4 introductory notes the third is very weak and high-pitched. The buzz is 1.0 to 1.5 sec in length, and the first 0.10 to 0.15 sec of it is louder and a little lower in pitch than the rest. The final high note, when present, is 0.10 to 0.15 sec in length. The long buzz is a series of abruptly down-slurred notes uttered 86 to 156 per sec; rather regularly through this buzz 1 or 2 notes are slurred downward further in pitch, producing a pulsating effect (17 to 43 pulsations per sec). The songs of a given bird may differ in the number of introductory notes; the buzzes of different birds usually differ in the note or pulsation rate, but these differences are seldom apparent to the ear. Occasionally, particularly when the bird is in flight, the song is followed by a buzzy trill a couple of seconds in length: a series of notes of one type, then a series of another type, and so on up to about 15 types, with the notes uttered 14 to 90 per sec; the songs of a given bird contain the same trills, but the trills of different birds are usually a little different (Smith, 1959).

32. *Sharp-tailed Sparrow.*—The song is about 1 sec in length and consists principally of a steady hissing buzz. The birds breeding in the interior of the country (*A. c. nelsoni*) usually begin their songs with a short buzzy note about 0.05 sec in length that is either a little lower or a little higher in pitch than the principal buzz of the song, and the songs end with a short buzzy note 0.05 to 0.20 sec in length and a little lower-pitched than the principal buzz: *p-cheeeeez-cul.* The birds breeding along the Atlantic coast from Maine (Popham Beach) north to the Gulf of St. Lawrence (*A. c. subvirgatus*) have similar songs, but the short introductory note is either lacking or low-pitched, and the song generally ends in a very short (0.01 sec in length) high note: *cheeeeez-cut-up.* The songs of birds breeding along the Atlantic coast from southern Maine to New Jersey (*A. c. caudacuta*) usually begin their songs with 1 or 2 short, high or low notes, and lack the final low note: *ch-ch-cheeeeez.* The songs of a given bird are essentially alike, but those of different birds often differ slightly.

33. *Seaside Sparrow.*—The song (fig. 18) begins with several very short (0.01 sec or less), sharp, usually very weak notes that are generally arranged in two groups, with 1 to 4 notes in each group; these notes are uttered 20 to 40 per sec, and the groups 8 to 10 per sec. The next (and loudest) part of the song, about 0.5 sec in length, contains several buzzy notes; these notes differ in different songs, but usually some are steady in pitch and some are slurred. The last part of the song, which is usually continuous with the last note in the second part, is a long hissing buzz lasting about 1 sec and fading out toward the end. Each bird may sing songs of 4 or more different patterns, which differ principally in the character of the first 2 parts of the song; the songs of different birds are usually a little different.

34. *Savannah Sparrow.*—The song consists of 1 to 4 short high-pitched notes uttered 3 to 4 per sec, followed by 1 to 3 short buzzy phrases a little lower in pitch and uttered 3 to 8 per sec, then 1 or 2 long buzzes about 0.5 sec in length, with the song usually ending in 1 to 3 short low-pitched notes. In songs with 2 long buzzes, the buzzes are separated by 1 to 4 (usually 1) short high-pitched notes, and the second buzz is lower in pitch and of a slightly different quality. The song lasts 2 to 3 sec. The songs of a given bird differ only in the number of introductory or final notes, and to some extent in the length of the buzzes; the songs of different birds are usually a little different.

35. *Baird's Sparrow.* The song generally consists of a high-pitched, often somewhat buzzy note, followed by 2 to 6 (usually 3 to 4) similar 2-note phrases uttered about 4 per sec, and ends in a buzzy trill; the first note of the song is usually the highest in pitch in the song, and the final trill the lowest. The final trill usually begins with 1 to 2 slightly longer notes, followed by a series of similar notes or 2-note phrases uttered 21 to 26 per sec; this trill is about 1 sec in length, but in some songs is lacking. The songs of a given bird are usually very similar,

differing only in the number of introductory phrases or in the length of the trill; occasionally a bird may sing songs of 2 or more slightly different patterns. The songs of different birds are generally a little different.

36. *Song Sparrow.*—The songs of this species are subject to an enormous amount of variation; they consist of a series of different phrases most of which contain 1 to 4 notes, and they usually contain a trill (12 or so similar phrases uttered too fast to count). Some notes are clear whistles, usually steady in pitch; some are buzzy. Most songs (fig. 19) begin with 2 to 4 (rarely 1 or 5) similar phrases uttered at a constant rate of 2 to 4 per sec; about one song pattern in five begins with 4 to 20 similar phrases that increase in rate (much as in field sparrow songs, but these notes are not always clear whistles). The longer phrases of the song (those uttered slowly enough to count) are usually single, but occasionally are repeated two or 3 times. Successive notes in a phrase, and successive phrases, are usually different in pitch, and the pitch range in a song is usually about 2 octaves. A given bird has a vocabulary of a large number of notes and phrases, which are variously combined to produce up to 12 or so song patterns; these song patterns are often quite different. A bird usually sings one pattern for a while before changing to another; in a several-minute period of singing it may go through a large part of its repertoire. The songs of a given pattern may vary in the number of phrases in particular parts of the song, in the presence or absence of certain phrases, or in the particular types of phrases with which the song begins or ends. The songs of different birds are nearly always different, though birds in the same area usually have identical phrases in their songs (Borror, 1956, 1957, 1961; Nice, 1943; Saunders, 1951b; Wheeler and Nichols, 1924).

37. *Lapland Longspur.*—The song (fig. 20) is musical and often somewhat tinkling, and consists of a series of phrases uttered 3 to 4 per sec; most songs contain 8 to 10 phrases, but occasional songs are longer. Most of the notes are musical in quality and steady in pitch, but many are uttered so fast that a buzzy effect is produced. The notes are mostly 0.01 to 0.10 sec in length, but many songs end in a longer note (0.25 to 0.30 sec in length) that slurs up and then down. Successive notes are nearly always different in pitch. In some parts of the song a liquid effect is produced by the overlapping of notes, i.e., one note beginning before the preceding note ends; some of the phrases resemble those of a wood thrush. The songs of a given bird are very similar, but those of different birds may differ slightly.

38. *Chestnut-collared Longspur.*—The song is loud, rather musical, somewhat similar in quality to the song of a western meadowlark, and is generally 2 to 2.5 sec in length. It consists of 5 to 10 (usually 7 to 8) phrases uttered 3 to 4 per sec; the phrases may contain from one to several notes. The 3 or 4 introductory phrases contain clear notes, and are of decreasing pitch; the final phrases are usually buzzy. The first phrase or two of the song are usually quite weak. The phrases are not repeated in a given song, but some phrases contain repetitive elements. The songs of a given bird are essentially alike, differing only in the character of the final weak phrases; the songs of different birds usually contain slightly different phrases.

39. *McCown's Longspur.*—The song is a fast warble, a little like the chattering of a house sparrow but more musical. The notes, nearly all of which are slurred, are mostly uttered 30 to 40 per sec, and successive notes are rarely alike or of the same pitch. There is some tendency for the notes to be grouped into phrases about 0.25 sec in length, but for the most part the phrases are more or less run together. The song sometimes contains 1 or 2 thin, high-pitched, slightly down-slurred whistles about 0.25 sec in length. The songs of a given bird usually vary in length, and sometimes also in the sequence of notes. A bird may sometimes, particularly when disturbed at its nest, sing almost continuously.

40. *Henslow's Sparrow.*—The songs are short (about 0.25 sec in length), high-pitched, and usually appear 2-parted: *tee-sick* or *se-lick*; the second part

is louder and lower in pitch. The song actually consists of 4 to 6 groups of notes, but the notes are uttered too rapidly for the ear to detect them all. The songs of a given bird are practically identical, but those of different birds may differ slightly (Borror and Reese, 1954).

41. *Evening Grosbeak.*—The principal sounds uttered by this bird are short chirping notes somewhat similar to some of the chirping of a house sparrow. The notes are of two general types, a relatively clear down-slurred note about 0.15 sec in length that begins abruptly, and a buzz 0.15 to 0.25 sec in length that usually slurs upward slightly and then downward. These two types of notes are not uttered in any definite sequence or at any definite rate, and the notes of different birds are very similar.

42. *Red Crossbill.*—This bird utters a variety of short notes, 2- and 3-note phrases, buzzes, and a few slurred whistles. The most characteristic utterance is a short, sharp, *kip-kip-kip*; these notes are abruptly up-slurred, and are generally uttered in groups of 2 to 4 or more, 3 to 4 notes per sec. Most of the notes and phrases are uttered 2.5 to 5 per sec, and they are apparently not uttered in any definite sequence. The notes and phrases of different birds often differ slightly.

43. *Snow Bunting.*—This bird utters a variety of low-pitched whistles, accented phrases, buzzes, and occasionally short trills. The whistles are usually slurred, and are 0.15 to 0.30 sec in length. The buzzes are steady in pitch or down-slurred, 0.10 to 0.25 sec in length, and are often harsh in quality. The phrases vary considerably; they may contain 2 to several notes, abruptly slurred elements, or buzzy elements. Many notes are uttered singly, 1 or more sec apart, producing a chirping effect; sometimes the notes and phrases are uttered in more rapid succession, 3 to 5 per sec, sometimes in a more or less definite sequence and sometimes in a varying sequence. These more rapid series sometimes end in a high-pitched, rather weak, clear whistled note that is usually down-slurred. Each bird utters a considerable variety of notes and phrases, and the phrases of different birds are usually different.

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A NEW SPECIES OF *DIPLOCARDIA* FROM FLORIDA

(OLIGOCHAETA; MEGASCOLECIDAE)

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This description is based on 20 clitellate and 6 aclitellate specimens which I collected in Columbia County, Florida, July 26, 1959. The specific location was 7 miles southeast of Lake City, along Route 245. All of this work has been accomplished during the tenure of research grant G-6378, awarded to me by the National Science Foundation.

Diplocardia bivesiculata n. sp.

Elongate, anterior and posterior ends somewhat swollen. Size, 165–215 by 2.5–3.0 mm. Somites, 190–241, average 212. Pigment lacking. Clitellum XIII–XVIII dorsally, XIII–½XVII ventrally. Setal formula, *aa*: *ab*: *bc*: *cd*: *dd* = 20: 7: 20: 10: 80. Protomium, epilobic, one half; margins converging. First dorsal pore in 10/11. Annulations, I–IV simple; V–XII, bi- or tri-annulate; post-clitellar annulations simple. Anus teminal. Tuberculae pubertates lacking. Nephropores are in setal line *d*, at anterior edge of each segment. Genital tumesences present as distinct papillae in setal line *ab* of VIII and IX; glandular area is present on ventral part of XXI or XXI–XXII. Genital setae; setae *ab* of XVIII and XX very small and confined to body wall. Spermathecal setae; setae *ab* of VIII and IX about twice the length of normal setae, distinctly curved, distal one-third strongly sculptured, tip hastate.

Spermathecal pores, two pair, in 7/8 and 8/9, on anterior edges of VIII and IX, in setal line *ab*. Spermiducal pores paired, between setal arc and anterior edge of segment in XIX, on outer edge of seminal gutter. Male field is flat, involves ½XVII–XX, between *a* setal lines. The seminal gutter is a nearly straight cleft with slightly raised edges, it involves ½XVIII–½XX. Prostate pores are two pair, equatorial, at ends of seminal gutters. Oviducal pores paired on oval flat field of mid-ventral XIV, located anterior to setal arc about one-half distance to anterior edge of segment.

Pharynx occupies II, III, IV. Pharyngeal glands compact, confined to II, III, IV. Gizzards two, in V and VI. Esophagus includes VII–XIV, ridged internally. Calciferous gland in XV and XVI; lamellae about 80 in number and free at inner margin. Intestine expands abruptly in XIX. Typhlosole weakly developed, begins anteriorly in XXIII; posterior ending variable between LIII–LXXIII. Septa 8/9 and 9/10 much thickened; 7/8, 10/11, and 11/12 thickened; 6/7 and 12/13 slightly thickened. Longitudinal musculature of pinnate type. Meganephridal; nephridia avesiculate, appearing first in II. Dorsal vessel doubled from XVIII (XIX, XX?) forward into VII; doubling is intrasegmental only, vessel simplex at penetration of each septum. Ventral vessel present; subneural vessel absent. Last hearts in XIII.

Testes, two pair, free, branching, in X and XI. Sperm duct without post-septal epididymal looping; generally free of parietes, ducts of each side joining within the body wall in XIX. Prostate glands two pair, in XVIII and XX. One pair of lobulated seminal vesicles in XII, from 11/12. Single pair of rather flattish ovaries in XIII; ova in multiple string; ovarian funnel conelike; ovisac absent; oviduct short and direct to body wall of XIV. Seminal receptacles are two pair, in VIII and IX; ampulla and duct about equal in length; ampulla sub-spherical and compressed; diverticulum small, deeply incised, located on anterior surface of duct near the point where the latter enters the body wall. Setal follicles not developed internal to parietes. Syntypes have been placed in the United States National Museum (U.S.N.M. Cat. No. 30006).

DISCUSSION

No striking variations in the digestive tract were noted among the specimens examined. The esophageal walls are quite vascular. In segments XV and XVI,

the gut wall does show a characteristic caliciferous gland development (fig. 1 F). Because the lumen is normally somewhat eccenteric, it is not possible to give the exact proportion of the gland occupied by the lumen, but at the height of lamellar development the inside measurements would be 0.067 x 0.40 mm and the respective outside measurements 0.60 x 0.94 mm. Generally, the lamellae are free at their inner ends although in a few instances, coalescence does occur forming interlamellar tunnels.

The typhlosole begins quite abruptly in XXIII; the posterior end is indistinct and can be established anywhere from LIII to LXXIII. The entire typhlosolar structure does not exceed 0.20 mm in height (fig. 1–E). Its dorsal surface contains a deep groove filled with blood. This groove, or typhlosolar sinus, is con-

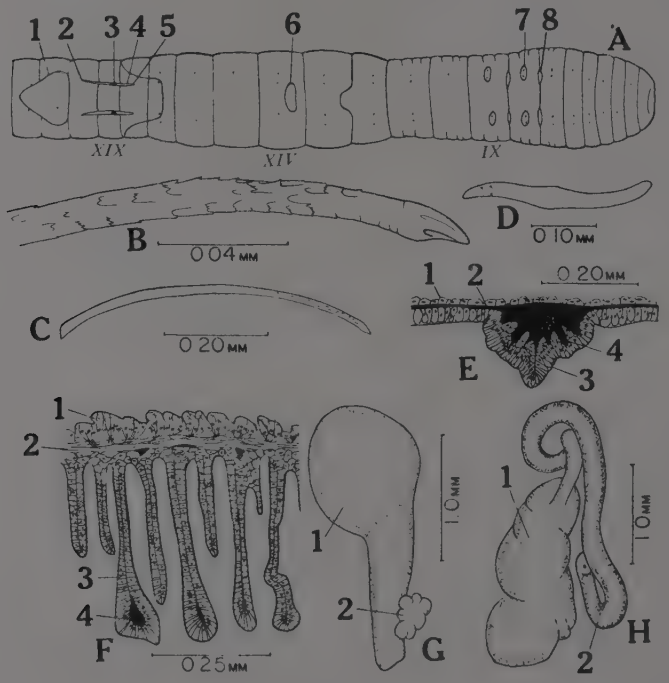

FIGURE 1

A. Diagram of ventral aspect of *D. bivesiculata*.—**1.** Glandular field of XXI–XXII. **2.** Position of prostatic pore of XX. **3.** Spermiducal pore. **4.** Seminal gutter. **5.** Position of prostatic pore of XVIII. **6.** Glandular field surrounding oviducal pores. **7.** Glandular area surrounding setae *ab*. **8.** Position of spermathecal pore in 7/8.
B. Distal portion of spermathecal seta IX *b*.
C. Spermathecal setae IX *b*.
D. Normal seta X *a*.
E. Typhlosole of XXX in cross section. **1.** Chloragogen cells. **2.** Intestinal blood sinus. **3.** Typhlosolar epithelium. **4.** Typhlosolar blood sinus.
F. Dorsal portion of caliciferous gland. **1.** Chloragogen cells. **2.** Muscle layer. **3.** Lamella of gland. **4.** Intra-lamellar sinus.
G. Spermatheca of segment IX.—**1.** Ampulla. **2.** Diverticulum.
H. Prostate of segment XVIII.—**1.** Glandular portion. **2.** Ectal portion of duct.

tinuous with the general blood sinus of the intestine, the Darmblutsinus of Hertling (1923).

Intra-segmental doubling of the dorsal vessel is easily determined from XVIII forward into VII. Behind XVIII, removal of the chloragogue layer reveals the vessel to be apparently doubled in XIX. In XX, the vessel is flattened and in this area it may be perforate medially. The simplex condition obtains at each point where the vessel penetrates a septum.

Sculpture of the spermathecal setae (setae *ab* of VIII and IX) is strong (fig. 1–B and C); the tip is hastate but subject to fracture so that this characteric must be used diagnostically with some care. Setae *ab* of XVIII and XX are exceedingly small. Their dimensions, based upon saggital sections, are estimated to be: 0.005 x 0.034 mm in width and length respectively. These setae, in each segment bearing them, are nearly contiguous and close to the prostatic pore. I could not find them in gross dissection.

The two pairs of spermathecae, in VIII and IX, are equal in size. The ampulla is ovoid, compressed, and contains some sperm. Similarly, the deeply incised diverticulum contains sperm and is located on the anterior side of the duct near its penetration of the body wall (fig. 1–H). Externally the spermathecal pore is obscure but an elliptical glandular spot surrounds the opening in 7/8 and 8/9 (fig. 1–A). This glandular area is actually confined to the anterior edge of VIII and IX but presses into the intersegmental furrow.

The prostates are similar in size and general form. The duct of each is thickened, coiled, and about twice the length of the glandular portion (fig. 1–H). The anterior pair of prostates occupy segment XVIII with the glandular part normally confined to this segment and with its long axis extending in a transverse plane. Anteriorly, the duct may extend a loop into XVII, but in no example studied did the duct penetrate XIX. The posterior postates, of XX, lie with their long axes in the antero-posterior plane; the glandular portion penetrates XXI and the duct may extend into XIX and XXI.

Although *Diplocardia bivesiculata* has but a single pair of small seminal vesicles in XII, segments X and XI are filled with sperm and it is probable that the cavities of these segments function as seminal vesicles.

Inasmuch as we do not know how much significance to attach to the various features presently employed in the diagnosis of diplocardians, intrageneric affinities are quite uncertain. Of the described species, *bivesiculata* would appear to stand close to *Diplocardia eiseni* (Michaelsen, 1894) in possessing: (1) a doubled dorsal blood vessel anterior to XX; (2) reduction in the setae of prostatic segments; (3) quadrithecate condition; and (4) the presence of a pair of hearts in XIII. The major differences between *bivesiculata* and *eiseni* would be: (1) reduction in number of seminal vesicles in *bivesiculata*; (2) position of spermathecal pores; and (3) the position of the calciferous gland.

Diplocardia bivesiculata was collected from the compacted soil of a vehicular trail through a slash pine forest. Worms were common along the trail and at its edges, but I could not find them in the forest floor proper. The understory of the forest was palmetto, oak saplings, shrubs, and dense grass cover.

Many of the soil castings were fresh and certainly had been produced within a few hours at most from the time of collection (3:00 PM). The digestive tract of all specimens examined was filled with sand from the upper soil layers and contained little organic material. In terms of habitat occupancy, *bivesiculata* is to be considered an upland soil species, in contrast to species preferring leaf litter, logs, or emergent shore lines.

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A NEW SPECIES OF HELIOPSIS FROM MEXICO[1]

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Since the monograph of the genus *Heliopsis* (Compositae) was published (Fisher, 1957), a new species was collected in the State of Chiapas, Mexico, by Dr. Robert Merrill King. Although it is known from only a single location it should be recognized as a specific taxon because of its distinctive morphology.

Heliopsis pulchra Fisher sp. nov.

Herba Perennis 15.0 to 40.0 cm alta; folia ovato-deltoidea, scabra, 1.5 to 2.0 cm lata, 3.0 to 5.0 cm longa, petioli 1.5 to 2.0 cm longi; capitula 1.0 to 1.5 cm lata, 0.5 cm alta; involucra 1-seriata; radii 10 to 12, aurei; achenia quadrangularia, 2.5 to 3.0 mm longa, irregulariter tuberculata.

Erect or ascending perennial herb, 15 to 40 cm tall, branched nearly to base; *stems* somewhat woody, 1.0 to 3.0 mm thick, sparingly pubescent below to strigose pubescent in lines above; leaves ovate to deltoid, 3.0 to 5.0 cm long, 1.5 to 2.0 cm wide below becoming progressively smaller above, strigose above and below becoming scabrous with age, densely strigose in axils of young leaves, petioles slender, 1.5 to 2.0 cm long, strigose in lines, margin of leaves finely toothed to nearly entire; *heads* (excluding rays) about 1.0 cm wide (in fruit); phyllaries in one series, appressed, strigose on both surfaces oblong-ovate, obtuse at apex; *rays* 0.8 to 1.0 cm long, 0.4 to 0.5 cm wide, often 2- or 3-lobed at apex, bright orange-yellow when young, turning light yellow with age; disk corollas yellowish, tube 3.0 to 4.0 mm long, glabrous to sparingly pubescent, lobes obtuse; pales lanceolate-oblong to spatulate, dull yellow at apex, 6.0 to 7.0 mm long, 1.0 to 1.5 mm wide; ray achenes triangular in cross section, outer surface curved, 2.5 to 3.0 mm long, surface irregularly tuberculate (fig. 1) very dark brown to black; disk achenes quadrangular in cross section, sharply so at apex, irregularly tuberculate, epappose or pappus represented by slight ridge (fig. 1).

Type Collection: Chiapas, Mexico: oak forests along route 190, about 5 miles northwest of Comitan where it grows abundantly in sandy soil and open sun, 25 June 1960, *Robert M. King 3049* (TEX; isotype deposited in The Ohio State University Herbarium).

The only other species of *Heliopsis* reported to date in the State of Chiapas, Mexico is *H. bupthalmoides* (Jacq.) Dunal which appears to be the nearest relative of this newly described taxon. The distinguishing differences between the two taxa are as follows:

H. bupthalmoides	*H. pulchra*
1. Achenes tan to light brown, rugose.	1. Achenes black, tuberculate.
2. Leaves ovate to ovate-lanceolate, approaching deltoid, pilose.	2. Leaves deltoid to slightly ovate, becoming scabrous.
3. Plants 30.0 to 75.0 cm tall.	3. Plants 15.0 to 40.0 cm tall.
4. Rays yellow.	4. Rays orange-yellow.
5. Phyllaries 2-seriate.	5. Phyllaries 1-seriate.

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[1]Publication 618 – Department of Botany and Plant Pathology, The Ohio State University.

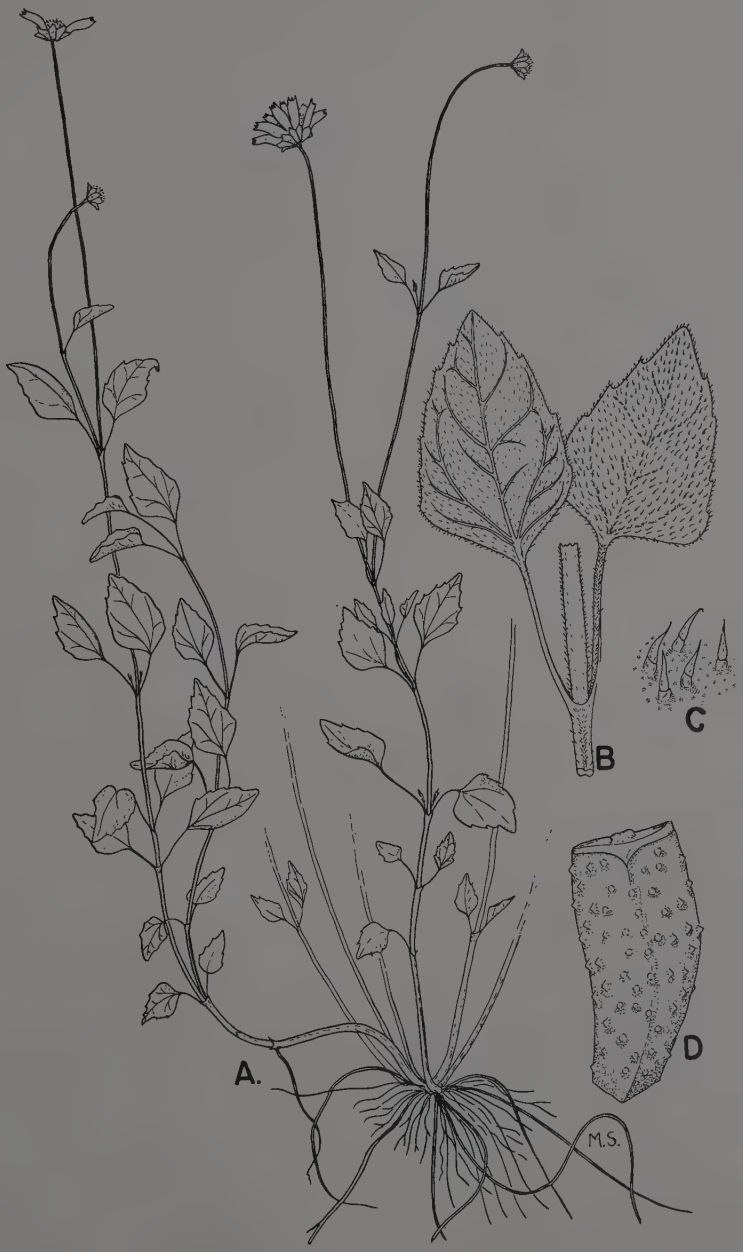

FIGURE 1. Detail drawings of portions of *H. pulchra* Fisher. A) Habit sketch of plant (¼ natural size). B) Portion of stem bearing mature leaves, approximately natural size. C) Pubescence on upper leaf surface ×30. D) Mature disk achene ×50.

EGG-LAYING IN THE SPOTTED TURTLE, *CLEMMYS GUTTATA* (SCHNEIDER)

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Little is known of the life history and nesting habits of the spotted turtle, *Clemmys guttata* (Carr, 1952). Babcock (1919) states that two to four eggs (averaging 30 x 17 mm) per clutch are laid in late afternoon or evening during the period June 10 to 25 in New England. In a later paper (1938), Babcock observed that nests were found among damp logs or moss and noted that the interval between deposition of the first two eggs was 15 min. Pope (1949) states that the hole is flask-shaped, near water, and that a clutch varies from one to four eggs. In the light of these scanty data, the following account should be of interest.

The observations were made of two females of *C. guttata*. The larger, measuring (straight-line) 5 in. carapace length, 3½ in. carapace width, and 2 in. shell height, was collected by Tony and Peter Mars on June 7, 1960, at Lexington, Massachusetts. I collected the smaller female (Kraig K. Adler n. 766), measuring 3¾ x 2⅞ x 1½ in., respectively, on June 27, 1960, in the Venetian Village canals, adjacent to the southeastern corner of Lake Maxinkuckee, Marshall County, Indiana. Both were kept in a large outdoor turtle pond located on the Culver Military Academy grounds near Culver, Indiana. The enclosure was shared with about 40 turtles of various local species of other genera.

Both turtles laid eggs during the evening of July 11, 1960. Rain was not associated with egg-laying; there was little moisture in the soil. The site selected by both was in the sandy earth around the shaded perimeter of the pool, about a half foot from the water, although the terrain several feet from the water appeared just as suitable. Ambient temperatures during the egg-laying period were 72° F at 6:35 PM, 70° F at 10:30 PM, and 67° F at 12:20 AM.

The larger turtle was first observed digging at 6:35 PM when the hole was already 1½ in. deep (all measurements are given along the slope of the hole, unless otherwise stated). The cylindrical hole was directed beneath the turtle and by 7 PM the lower end was slightly larger, thus making the cavity flask-shaped. The depth at this point was 2 in. At 8:18 PM, the hole was 3¾ in. deep (about 2½ in. vertical depth, 2½ in. diameter at the mouth). The hind legs were used successively, each one scraping the opposite side of the hole; after one leg had been used for about six strokes, the other was used for a like number of times. Rests, about 30 sec long, between changes of legs became more frequent as digging approached termination; a 14 min rest occurred between termination of digging and the deposition of the first egg at 9:14 PM. The egg was pushed around with the hind legs in the enlarged cavity. The second egg (9:15 PM) was pulled and extracted from the cloaca with the aid of the hind feet. Then a little dirt was pushed into the hole. The next six eggs were laid at 9:20, 9:21, 9:24, 9:25, 9:29, and 9:41 PM, and were all pushed around with the hind legs. After adjusting the eggs and with few rests, the turtle started to fill in the hole at 9:45 PM. The last egg disappeared beneath the soil at 9:49 PM (this egg was 1 in. below the surface of the ground on the slope). Both legs were used alternately to cover up, one or two strokes each. By 10:04 PM the hole was completely covered and the turtle searched with only her hind legs for excess dirt; the loose dirt was then patted down with the posterior portion of the plastron and the hind legs. The turtle's head was completely withdrawn throughout the whole process following egg-laying. The animal entered the water at 10:14 PM and had considerable difficulty in

stabilizing herself; the anterior end was lower in the water than the posterior. She clawed at her tail by using both hind feet until well after 11 PM, when she could swim almost normally.

The smaller turtle began digging near a small clump of grass about three ft from the larger specimen. Her digging was first observed at 6:45 PM when the hole was 1½ in. deep. By 7:45 PM it was 2¾ in. in depth (1¾ in. diameter at the mouth). Digging with the hind feet was essentially similar to that of the larger turtle, except that the right leg appeared to be employed more than the left. At 8:11 PM a small rock was encountered and after attempts to dislodge it proved futile, the course of the hole was altered slightly. By 10:30 PM the hole was 3 in. deep, and the rests between shifts of legs became more frequent, although these rests were not quite as long as in the larger female. The first two eggs, dropped at 11:28 and 11:32 PM, respectively, were pushed around with the hind legs. The third and last egg was laid, with apparent difficulty, at 11:37 PM; part of the cloaca became extended and was pink in coloration. The turtle began covering the nest immediately and the last egg disappeared from view at 11:55 PM (this egg was ½ in. from the surface on the slope). By 12:13 AM (July 12) the hole was completely covered and the turtle reached out with the hind legs apparently in search of excess dirt. She then patted the loose dirt down in the same manner employed by the larger specimen. She entered the water at 12:45 AM and had less trouble than the larger female did in stabilizing herself. By 12:50 AM she too was picking at her tail with the hind legs, an action which continued until after 1 AM.

On July 14, 1960, both nests were opened and the eggs measured (table 1).

TABLE 1

Measurements of two clutches of Clemmys guttata *eggs 3 days after deposition (in cm)*

Egg number	1	2	3	4	5	6	7	8	avg
Larger female:									
length	2.5	2.9	2.5	3.0	3.1	3.0	3.1	3.1	2.9
width	1.6	1.7	1.6	1.7	1.7	1.8	1.8	1.7	1.7
Smaller female:									
length	2.6	2.9	2.9						2.8
width	1.6	1.7	1.7						1.7

In the clutch of the larger turtle, the eggs were in two levels of four each; in that of the smaller, one egg was in the lower level and two in the upper. Since most accounts list four as the maximum number of eggs per complement, it is of interest that the larger specimen laid eight. However, Blake (1921) examined five specimens, three of which had oviducal egg counts of 9, 9, and 11. Perhaps due to the dry, sandy soil in which the eggs were buried, all failed to hatch; one egg from the larger clutch was opened on August 10 and found to be fertile.

It may be sheer coincidence, or it may be the result of response to some unknown factor that both turtles laid their eggs on the same night, even though they had been obtained from localities about 800 miles apart. My presence did not seem to affect the turtles in the nesting procedure; they did, however, withdraw their heads with a faint hiss as a ruler was inserted into the hole to record depth. There was no cloacal discharge of urine by either turtle. Babcock (1938) states that there is a 15 min interval between the deposition of the first and second eggs; in the two females observed here, the interval was 1 and 4 min, respectively. Throughout the whole process, neither turtle visually examined the hole or nesting site, even after egg-laying was completed. Clement (1958) found that *Clemmys insculpta* turned around to examine its nesting site. This observation was made under unnatural conditions, however.

Pallas (1960) has also given an account of *C. insculpta* but under more natural conditions than Clement. Most of her remarks are applicable to both species (and perhaps most turtles, for that matter), but there are a few differences, *C. guttata* rested occasionally in the digging process, *insculpta* did not. Both species rested during the covering-up process. While digging, the spotted turtle extended the head only slightly; while covering the eggs, the head was completely withdrawn. *C. insculpta* extended its head fully at both times (Clement, op. cit., writes that his specimen frequently withdrew its head and snapped; however, this specimen was held in hand during egg-laying). *C. guttata* dug about six successive times with one leg before using the other; *insculpta* used each leg alternately.

I should like to acknowledge the generous assistance of John L. Curry in taking notes. I am also grateful to Clifford H. Pope, Norman E. Hartweg, Aubrey S. Bradshaw, and Robert E. Gordon for a critical reading of the manuscript.

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Practical Astronomy. *W. Schroeder.* Philosophical Library, New York, 1957. xi+206 pp. $6.00.

Mr. Schroeder, a member of the British Astronomical Association, has written a very interesting and useful book in conformance with the high standards of his organization. We shall not quarrel about the title: this book is not what is usually meant by "practical astronomy" that is, the mathematical treatment of the problems of determination of latitude, longitude, azimuth, etc.

The subtitle to Schroeder's book reads "A New Approach to the Old Science" and he has no hesitation of putting in excellent maps and descriptions of constellations (ch. 3 and 16), discussion of a small telescope and what can be seen with it (ch. 15), problems of navigation, (ch. 10), discussion of ancient and medieval astrolabes (ch. 9), sun-dials (ch. 8), etc.

The most unusual, and welcome, feature is the approximate calculation of the apparent position of the sun, moon and planets (ch. 11 and 12). The stumbling block here is the extreme complexity of equations properly treated in the texts on celestial mechanics. To calculate the precise longitude of the moon, for instance, it is necessary to handle 1,500 terms. Students even with good mathematical background often fail to see the wood for the trees. Students (and teachers also) seldom realize that cutting down the expression for the longitude of the moon to six terms, it is possible to calculate the moon's position with a precision of 10 minutes of arc, which is all that is necessary for the naked eye observations. This is the precision actually achieved by Kepler at the beginning of the 17th century.

Mr. Schroeder does exactly that. Instead of analytical expressions for lunar inequalities, he gives graphs from which various corrections to the mean position of the moon can be read off. The same procedure is employed for the planets. The principle of the determination of exact positions of the moon and planets becomes quite clear.

The book is written for an "intelligent layman" who wants to understand the principle of astronomy, with a bit of astrophysics thrown in. It is also an excellent collateral reading for college students who are taking elementary courses in astronomy without much mathematical background. It is also a good reference book for a teacher in astronomy, showing as it does how many complicated things in astronomy can be made simple and understandable without sacrificing too much of precision.

N. T. Bobrovnikoff

A GENUS OF ANOBIIDAE UNRECORDED FROM THE UNITED STATES (COLEOPTERA)

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During a recent study of the Anobiidae of Ohio, I discovered four similar specimens in material borrowed from the United States National Museum which could not be placed in any genus known to be indigenous to the United States. Since the localities of collection are coastal, or nearly so, the possibility immediately arose that they represented a foreign genus and had been introduced into the United States. The specimens were identified as belonging to the European genus *Mesocoelopus*, and, at the suggestion of J. N. Knull, one was sent to the British Museum of Natural History. The generic determination was confirmed by E. B. Britton, Principle Scientific Officer, who further found that the material agreed exactly with a specimen of *M. collaris* Muls. & Rey (determined by Maurice Pic) in the collection.

The genus *Mesocoelopus* is nearly world-wide in distribution and until 1956 consisted of 25 known species. It is known from Europe, Africa, Madagascar, Sumatra, Java, Cuba, Costa Rica, and Guadeloupe, but has not, until now, been recorded from the American continent. For the benefit of American workers a description of the genus and species as derived from the four specimens follows.

MESOCOELOPUS DuVal

Mesocoelopus DuVal, 1860, p. 143.

Elongate oval; pubescence short, recumbent, moderate in density; punctures very fine, dense.

Head rather large, front evenly convex, moderately impressed beneath for antennae; eyes rather small (separated by about two times vertical diameter); antennae 11 segmented, serrate, last three segments not elongate; maxillary palpi elongate, somewhat triangular, inner angle curved; labial palpi broadly triangular, inner angle acute.

Pronotum nearly evenly convex but humped posteriorly at middle; scutellum pointed posteriorly, nearly triangular; elytra lacking striae, punctures somewhat larger than on rest of body.

Beneath: front coxae depressed, contiguous, concealed in repose; mesosternum nearly vertical posteriorly, broadly impressed in middle; middle coxae widely separated; anterior median edge of metasternum produced into a short, broad, ventrally directed hook-like process; metasternum nearly evenly convex from side to side; metepisterna narrowly exposed anteriorly, rather broadly so posteriorly; hind coxal plates somewhat wider laterally; first abdominal segment excavated for hind legs, visible at middle between coxae; segment 2 long, about equal to fifth, segments 3 and 4 rather short, equal; front tibiae normal, not concave or grooved on outer margin; first segment of tarsi equal to three following.

The genus *Mesocoelopus* belongs to the subfamily Dorcatominae and is most closely related to *Catorama* and *Cryptorama*; it appears nearly intermediate between the two in body form and other characters. It can be distinguished from both genera by antennal characters. The antennae of *Mesocoelopus* are 11 segmented, serrate, and the last three segments are not enlarged; those of *Catorama* and *Cryptorama* are not serrate and the last three segments are greatly enlarged. These organs are 10 segmented in *Catorama* and 11 segmented in *Cryptorama*.

Fall (1905) states that the metasternal hook-like process is an absolutely unique structure of *Catorama*; with the discovery of *Mesocoelopus* this is no longer true.

Mesocoelopus collaris Muls. & Rey

Mesocoelopus collaris Mulsant & Rey, 1864, p. 324.

Elongate oval, about 1.76 times longer than wide; light reddish brown to reddish brown above with rather darker areas evident, antennae (except first segment), front legs, and tarsi yellow to reddish yellow; body moderately shining; pubescence short, recumbent, moderate in density, yellowish, nearly uniform throughout; punctures very fine, dense, nearly uniform throughout.

Eyes rather small, separated by about two times vertical diameter; antennae a little longer than pronotum, segment 2 faintly triangular, longer than wide, 3 triangular, slightly longer than wide, 4 and 5 nearly pyramid-shaped, 4 as wide as long, 5 a little wider than long, 6 triangular, a little wider than long, 7 to 10 each slightly larger than 6, strongly triangular, about as wide as long, segment 11 one-half longer than 10, elongate oval, somewhat pointed; maxillary palpi elongate, nearly two times longer than wide, outer angle rather acute, inner angle rather broadly rounded; labial palpi broadly triangular, as wide as long, outer angle nearly a right angle, inner angle distinctly acute.

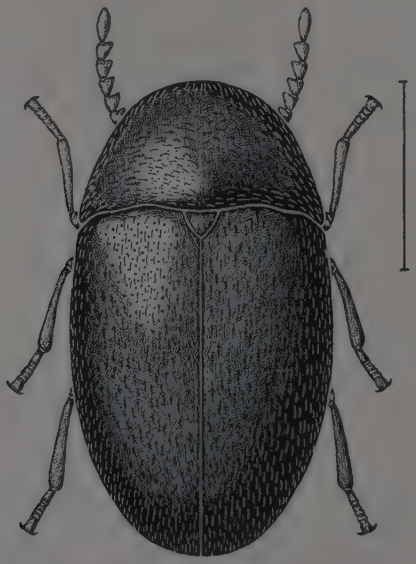

FIGURE 1. *Mesocoelopus collaris* Muls. & Rey (line equals 1 mm)

Pronotum humped posteriorly at middle, most obvious in lateral view, surface of elevation finely, rather densely granulate, basal margin sinuate; elytra as wide as pronotum, nearly evenly convex in lateral view, lateral margin finely serrate, most clearly so on posterior half.

Abdominal sutures broadly sinuate.

Length: 2.1 to 2.7 mm; width: 1.2 to 1.5 mm.

Redescribed from four specimens of unknown sex. One collected from Coatesville, Pa., May 28, 1948, by S. W. Bromley, labeled "with bored English ivy;" two from Roanoke, Va., June 19, 1933, E. M. Funkhouser, from same host; a fourth labeled Washington, D. C., collector Chittenden. Three specimens deposited in the United States National Museum and one in The Ohio State University collection.

My thanks to J. N. Knull and J. G. Rozen for assistance during preparation of the manuscript, and to T. Spilman for loan of material.

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Constructing an Astronomical Telescope. *G. Matthewson.* Philosophical Library, Inc., New York, Second edition, 1957, xii+100 pp. $3.00.

This small volume sets out to provide the interested hobbyist with the essential background and instructions to enable him to acquire, by his own hands, a good quality reflecting telescope, whether or not he has previously attempted the working of optical parts. Covered in detail are the general requirements for design, mirror grinding, polishing, figuring and front silvering of a small parabolic mirror and in less detail the mechanical design and constructior of an astronomical telescope and suitable mounting.

The author, as a professional in another field and an amature scientist, covers too vaguely the aspects of the problem which the professional would feel fundamental to the problem, but he sets forth adequately the problems of grinding, polishing, and figuring. The discussion of optical testing leans heavily on the mechanical preparation and lightly on the meaning and interpretation of the observed patterns. Throughout, the reader is expected to learn the significance of short discussions by encountering the circumstance in the actual making of a mirror.

While the author discusses various types of equatorial mountings in the broad sense and makes very well the essential point of rigidity of the mounting, the mechanical design and problems of fabrication are left with the reader despite the inclusion, in this edition, of a new chapter briefly describing the author's own mounting.

The book is useful as a brief survey of the problem of telescope construction and as a manual for the fabrication of a mirror. A professional in the engineering or scientific fields could use this book to build an instrument. The man-in-the-street might find it too brief.

KENNETH E. KISSELL

An Introduction to Astronomy. *Robert H. Baker.* D. Van Nostrand Co., New York, 6th edition, 1961. (No price stated).

This is a new edition of the well-known text, "the little Baker," to distinguish it from the larger text by the same author, "the big Baker."

The book under review is well suited for a short course in astronomy on a freshman level. The development of astronomy is shown by the fact that the 4th edition of the book (1952) had 306 pages, the present edition has 364 pages.

The author has evidently taken care to bring up his book to date, but it is doubtful that any text-book can keep up with such a rapidly developing science as astronomy. Chapter 8 on the planets, for instance is only 30 pages long, taking out illustrations not more than twenty, and many recent results are not mentioned. To such an important subject as meteorites the author devotes not more than three pages of text. However, these are minor points; the book evidently had to be kept within certain bounds.

Our criticism is of another kind. What are freshman students supposed to get in their astronomy course? A collection of thoroughly verified facts, strung one after another in an endless procession? If so, Baker's books are certainly among the best available.

On the other hand if the teacher thinks that his students should get a picture of an intellectual adventure of mankind, with Babylonian-Egyptian astronomy in the background, a jolt to medieval science delivered by Copernicus, and a rapid development of observational and computational technique after Newton, he should look for another book: Baker has nothing to say about that.

N. T. BOBROVNIKOFF

REACTION BETWEEN ALPHA-METHOXYPHENYLACETIC ACIDS AND ZIRCONIUM

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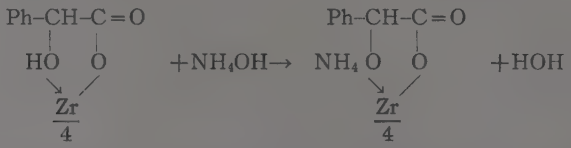
Mandelic acid, *p*-chloro- and *p*-bromomandelic acids are recognized reagents for the gravimetric determination of zirconium. Some doubt exists as to the nature of the precipitate formed between zirconium and these reagents. Kumins (1947), the discoverer of the reaction, believed that the compound formed with mandelic acid was a simple salt, i.e., $Zr(C_8H_7O_3)_4$. Feigl (1949), however, proposed a chelate-type structure to explain the solubility of zirconium mandelate in aqueous ammonia. Feigl supposed that complexation enhances the acidic character of the hydroxyl hydrogen in mandelic acid to such an extent that it is capable of being replaced by ammonium ion to form the ammonium salt.



Some evidence as to whether or not this is so could be obtained by replacing the hydroxyl hydrogen in mandelic acid with a methyl group, i.e., by synthesizing α-methoxyphenylacetic acid and testing its reaction with zirconium ion. The methyl group would be expected to be less labile than the original hydrogen and possibly to interfere with the formation of the zirconium chelate. On the other hand it should not influence extensively the precipitation reaction, if the product is a simple salt.

This paper describes the preparation of α-methoxyphenylacetic acid and also the *p*-chloro- and *p*-bromo-derivatives and their testing for reaction with zirconium in solution.

Reagents

Alpha-methoxyphenylacetic acid was synthesized according to the procedure of Reeve and Christoffel (1950). One mole of mandelic acid was reacted with 13 moles of sodium hydroxide to form the sodium salt. To this was added slowly 5.5 moles of redistilled dimethyl sulfate to form the sodium salt of α-methoxyphenylacetic acid. The methylated and unmethylated salts were separated by crystallization from an acid solution of pH 3.1, the sodium salt of α-methyoxphenylacetic acid being much less soluble at this pH. This sodium salt was then converted to the free acid by treatment with hydrochloric acid.

$$C_6H_5 \cdot CHOH \cdot COOH + NaOH \rightarrow C_6H_5 \cdot CHOH \cdot COONa + HOH$$

$$2C_6H_5 \cdot CHOH \cdot COONa + CH_3O{-}S(=O)_2{-}OCH_3 \rightarrow 2C_6H_5\,CHOCH_3 \cdot COONa + H_2SO_4$$

$$C_6H_5 \cdot CHOCH_3 \cdot COONa + HCl \rightarrow C_6H_5 \cdot CHOCH_3 \cdot COOH + NaCl$$

The acid was then extracted with ethyl ether and the ether was evaporated to give the solid acid. The *p*-chloro- and *p*-bromo- derivatives were synthesized in a

similar manner, starting with *p*-chloro- and *p*-bromo-mandelic acid. Results are given in table 1.

TABLE 1

Melting point (°C) and yields of methoxy acids

Name	Lit. mp	mp	% yield
α-methoxyphenylacetic acid	70–71	67–69	23
p-Cl-α-methoxyphenylacetic acid	85–86	84–85	36
p-Br-α-methoxyphenylacetic acid	95.5–97	96–96.8	24

Analytical Procedure

A zirconium solution calculated to be 0.05 M was prepared from recrystallized zirconyl chloride octahydrate. This was standardized by gravimetric analysis using mandelic acid, *p*-chloro- and *p*-bromo mandelic acids according to the procedures of Kumins (1947) and of Klingenberg and Oesper (1949). The results are given in table 2.

TABLE 2

Preparation of standard Zr solution

Reagent	ZrO_2 found
Mandelic Acid	.0586 gm
	.0588 gm
	.0588 gm
	.0585 gm
p-chloromandelic acid	.0590 gm
	.0590 gm
p-bromomandelic acid	.0590 gm
	.0590 gm
	Value Used .0590 gm

A 0.1 M solution of α-methoxphenylacetic acid was tested with the standardized zirconium solution. To a mixture of 10 ml of standard zirconium solution, 10 ml of concentrated hydrochloric acid, and 30 ml of water warmed to 65° C was added the 0.1 M α-methoxyphenylacetic acid. This approximates the conditions for the precipitation of zirconium with mandelic acid. No precipitate formed. Several other solutions containing less hydrochloric acid were run and precipitates containing zirconium appeared, but the zirconium oxide obtained on ignition did not correspond to the amount of zirconium added. The results appear in table 3.

When mandelic acid was added to the filtrate from two of the samples, a further precipitation of zirconium occurred. When this precipitate was added to the crucibles, burned, and the weight of residue added to the original, the total was only 0.0001 to 0.0004 gm from the standard. This indicated zirconium was definitely present in the original precipitate, otherwise the final results would have been high. The nature of the precipitate was further investigated.

The effect of ammonium hydroxide on the precipitate was studied since it dissolves the zirconium precipitate of mandelic acid to form the aforementioned complex. Upon addition of ammonium hydroxide to the system, the precipitate present appeared to dissolve. Further examination showed that zirconium

hydroxide was appearing. This indicates that the precipitate is not of the same type as that obtained with mandelic acid.

TABLE 3

ZrO^{++} vs. α-methoxyphenylacetic acid

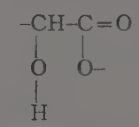
Amt. HCl used	Wt. Residue as ZrO_2
10. ml	0.0000 gm
5. ml	0.0168 gm
4.5 ml	0.0275 gm
3.5 ml	0.0276 gm
2. ml	0.0473 gm
	Amt. Added 0.0590 gm

Since the *p*-chloro- and *p*-bromo- derivatives were insoluble in water they were added as powder to a hot zirconium solution and stirred to form an emulsion. The solution became cloudy as a result of some of the acid oiling out but no zirconium precipitate appeared. Varying the pH also failed to precipitate zirconium with the *p*-chloro- and *p*-bromo- α-methoxyphenylacetic acids.

Discussion

From the evidence obtained in the experimental work with α-methoxyphenylacetic acids, it is apparent that the replacement of the alcoholic linkage of mandelic acid with an ether linkage definitely blocks the precipitation of zirconium. The zirconium binding force of the glycolic group, -CHOHCOOH, is completely destroyed when the methyl group is substituted and the sample is run at normal hydrochloric acid concentration of the mandelate method. The destruction of the zirconium—binding force may be due to both inductive effects and steric hindrance.

In the glycolic group,



both oxygens are negatively charged and form a precipitate with the positively charged zirconium ion quite easily. The hydroxyl hydrogen offers little or no blocking effect. However, when the methyl group is introduced in place of the alcoholic hydrogen, two new factors enter into the structural behavior of the acid. One is the fact that the methyl group is an electron donor, and helps satisfy the electronegativity of the adjacent oxygen atom. The ether oxygen thus formed is comparatively neutral, and no longer attracts zirconium ions. The other factor involves the blocking effect of the methyl group. This group, being much larger than the single hydrogen, would stearically hinder the formation of the zirconium chelate precipitate.

The fact, then, that α-methoxyphenylacetic acid and the *p*-chloro- and *p*-bromo- derivatives do not behave like mandelic acid and its *p*-chloro- and *p*-bromo- derivatives indicates that the mandelates are not simple salts, but are instead chelates.

Acknowledgment

We wish to express our sincere gratitude to the National Science Foundation whose grant supported this research.

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ADDITIONS TO THE STATE AND COUNTY RECORDS OF OHIO DRAGONFLIES (ODONATA)

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The Odonata, as pointed out by Alrutz (1959), have not been thoroughly studied in the state of Ohio. Several workers, primarily Borror, Price, and Alrutz, have published additions to and extensions of the original work of Kellicott on the distribution of dragonflies in Ohio. Alrutz (1961) has a complete bibliography of the various individuals who have published papers on Ohio Odonata. These workers have brought to 146 the number of species of dragonflies reported for the state.

This paper will bring to 147 the number of species reported from Ohio. In addition 49 new county records for 34 species, plus extension of the seasonal range of two rare Ohio dragonflies, are reported.

All the specimens listed in this paper are in our collections. Individuals who have collected specimens cited in this paper are: Robert W. Cruden (RC), Neva L. Currie (NLC), and Richard White (RW).

All the new records from Summit County were collected by R. White during the summer of 1958 and include six new species for that county. The majority of records are those of the junior author, who has done considerable collecting in central Ohio. Specimens cited below were identified by one or both authors. Identification of *Cordulia shurtleffi* Scudder, the new state record, and *Ischnura prognatha* (Hagen), second record for the state, were verified by Dr. D. J. Borror, Department of Zoology and Entomology, The Ohio State University.

The new record for the state is number 147 *Cordulia shurtleffi* Scudder. Two males of this species were collected at Fern Lake Bog in southern Geauga County on 6 June 1960 by the senior author. One specimen is in the collection of the senior author and the second is in the collection of the junior author. The two specimens were captured without too much difficulty late in the day (6:30 to 7:30 PM). Although observed for only a short time each male appeared to have a fairly distinct territory established at the edge of the bog mat. Several females were observed ovipositing just within the edge of the mat in small open areas. When approached they flew into the tall vegetation which borders the bog. At least a dozen individuals were seen during the course of the four to five hours spent at the bog.

C. shurtleffi is a northern species. It has been reported from Michigan, Pennsylvania, New Hampshire, New York, Massachusetts, and Canada, including Ontario (Needham & Westfall, 1955). Thus it is not surprising that it has finally been collected in Ohio, and even less surprising that it was first collected at Fern Lake Bog, which is a good example of a northern bog. Tamarack rings the eastern side and many other relic and bog species grow on the mat or in the surrounding woods. It is likely that this species will be collected in similar habitats throughout northern Ohio.

NEW COUNTY AND EXTENSION OF SEASONAL RANGE RECORDS

Whenever possible, in the taxonomic treatment, the numbers assigned to each taxon and the order of the taxa follow those of Alrutz (1961).

12 *Gomphus* (*Gomphus*) *graslinellis* Walsh
Marion (NLC)

14 *Gomphus* (*Gomphus*) *lividus* Selys
Summit (RW)

22 *Gomphus* (*Arigomphus*) *villosipes* Selys
Portage (RC)

31 *Anax junius* (Drury)
Lorain (NLC)

34 *Epiaeschna heros* (Fabricius)
Marion (NLC)

48 *Neurocordulia yamaskanensis* Provancher

On 17 June 1957, a teneral female was collected on Gibralter Island, Ottawa County, and two weeks later a male and female were collected on this same island. This extends the seasonal range from June 26 to 28 as given by Borror (1937) to June 17 to July 1. This rare Ohio species immerges and is quite plentiful on Gibralter during the last two weeks of June, during which time it is easily collected.

49 *Epicordulia princeps* (Hagen)
Marion (NLC), Perry (NLC)

55 *Celithemis elisa* (Hagen)
Delaware (NLC), Franklin (NLC), Marion (NLC), Summit (RW)

56 *Celithemis eponina* (Drury)
Marion (NLC), Perry (NLC)

62 *Libellula cyanea* Fabricius
Pike (RC)

68 *Libellula semifasciata* Burmeister
Marion (NLC)

65 *Plathemis lydia* (Drury)
Summit (RW)

73 *Sympetrum rubicundulum* (Say)
Delaware (NLC)

74 *Sympetrum semicinctum* (Say)
Portage (RC)

76 *Sympetrum vicinum* (Hagen)
Morrow (NLC)

71 *Tarnetrum corruptum* (Hagen)
Ottawa (RC). A male of this uncommon species was captured in low vegetation at the edge of Fischer's Pond, Middle Bass Island, 25 June 1958.

77 *Leucorrhinia intacta* (Hagen)
Delaware (NLC), Summit (RW)

81 *Pantala hymenea* (Say)
Marion (NLC)

82 *Tramea carolina* (Linnaeus)
Delaware (NLC)

87 *Agrion maculatum* Beauvais
Summit (RW)

90 *Archilestes grandis* (Rambur)
Franklin (NLC)

92a *Lestes disjunctus australis* Walker
Huron (NLC), Perry (NLC)

96 *Lestes rectangularis* Say
Delaware (NLC), Marion (NLC)

97 *Lestes dryas* Kirby
Delaware (NLC)

98 *Lestes unguiculatus* Hagen
Delaware (NLC), Fairfield (NLC)
100 *Argia apicalis* (Say)
Perry (NLC)
104 *Argia tibialis* (Rambur)
Morrow (NLC)
110 *Enallagma antennatum* (Say)
Marion (NLC)
111 *Enallagma aspersum* (Hagen)
Delaware (NLC), Marion (NLC)
129 *Enallagma basidens* Calvert
Delaware (NLC), Fairfield (NLC), Marion (NLC)
114 *Enallagma civile* (Hagen)
Perry (NLC)
119 *Enallagma geminatum* (Hagen)
Delaware (NLC), Marion (NLC)
121 *Enallagma signatum* (Hagen)
Delaware (NLC)
122 *Enallagma traviatum* (Selys)
Perry (NLC)
125 *Ischnura prognatha* (Hagen)

Marion (NLC). A single male of this species was taken 25 May 1959 near a small pond in the Delaware Reservoir Wildlife Area. This was the second time this species had been collected in the state. The previous record is from Hocking County, 20 April 1930 (Borror, 1935). This gives a seasonal range of April 20 to May 25.

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Algeria: The Realities. *Germaine Tillion.* Alfred A. Knopf, N. Y. 115 pp. $2.50. Translated from the French by *Ronald Matthews.*

This book about Algeria was written for the people of France, but it presents with great clarity the problems confronting the world of "haves" and "have nots." It portrays the catastrophe of those peoples who have existed with (and perpetuated) archaic cultures, i.e., ¾ of the human race, in this period of expansion of the industrialized western world, i.e., ¼ of the human race.

The author is a French woman, a sociologist and teacher at the Sorbonne. She saw this catastrophe overtake a small community in Algeria where she lived 1934–1940 and knew then every individual in the region. They were all very poor, but they had enough to eat, and were pleasant, good natured, warm-hearted people, enjoying, ". . . a well-balanced existence, thanks to the unlimited mutual aid that linked the inhabitants of a village or a group of tents, the pride they took in the solidarity, the enormous fun they got out of playing dirty tricks on their neighbors and the relative harmlessness of these pranks."

"When I saw them again, between December, 1954, and March, 1955, I was thunderstruck by the change they had undergone in less than fifteen years, and for which the only word I can find is "pauperization." These men who fifteen years before had been living sparingly but reasonably, and in conditions that were more or less the same for everyone, were now split into two unequal groups. In the smaller group, it is true, people were richer than in the old days, but in the other group no one could be sure how he was going to exist between December and June. In the old days, after a good harvest, even the poorest man would put the surplus by for

consumption over the next three years, for centuries of experience had taught everyone the need for providence. Now nine families out of ten were living from hand to mouth."

"What lay behind it all? There is no lack of explanations—shiftlessness, Moslem fatalism, French colonialism, the shrinkage of culturable lands caused by sand-laden winds and/or goats.

"France's contribution" to the country was, to all appearances, conspicuous by its absence: not a single teacher, an empty road, no medical officer, no nurse, no sort of emissary of "civiliza; tion." At the most it had amounted to a few good intentions, which had never followed up."

"The appearances, however, were completely misleading. "France's contribution" was everywhere, invisible but omnipresent, and was distributing good and evil with an open hand. Good and evil, however, are a little difficult to distinguish here."

"True there are no regular medical rounds, and therefore no periodical distribution of aspirins or lozengers, but plague and cholera had gone before 1940, and malaria, typhus and typhoid (rampant in 1940) had disappeared by 1954. Famines and tribal wars were becoming mere legends."

The population had shot up to four or five times that of 100 years earlier, and the rate of increase is still going up. "As the people have been multiplying, their flocks and farms have been expanding and have reached and then passed what might be called the danger line, beyond which the soil is irreparably exhausted, springs dry up, and forests vanish once and for all."

". . . meantime—the peasants have stopped reckoning in loads of barley and are counting in francs; they have passed almost unawares from a barter economy to a market economy."

"This (vicious) cycle, starts when the peasant is forced to sell his produce immediately after the harvest in order to pay off his debts—to sell at the bottom price. It continues when five or six months later he is compelled to buy the same produce back at the top price—so he gets deeper and deeper into hopeless difficulties."

"The sudden and unprecedented increase in population, the simultaneous dwindling of resources, the collapse of the economy, and contact with the heart-breaking superiority of foreign techniques are rocking to their foundations the archaic civilizations that have been subjected to this combined offensive. Everything they could boast of is dying or on the point of death; art, techniques, and all the ingenious devices that permit a human community to live in some-thing like peace. In every field the seedy and the sordid are on their way to replacing the splendid survivals of the past."

"The new era (emergence from the Middle Ages) began with the enormous development of mechanization, the huge expansion in trade and the increased speed of transport, and above all, with the great medical discoveries. Along with these phenomena went universal education, the increase of technical skill, and a regular increase in wealth."

"All this—the *world-wide* stamping out of epidemics, the *world-wide* commercialization of resources, the *world-wide* dissemination of ideas, discoveries, and news—has resulted in the transforming of the human biological environment all over the world."

"Now, part of mankind has adapted itself to the new environment and has gained hand-somely from it. The rest of the people did not succeed in adapting themselves at once, and thus started to fall behind, and so every year it is becoming a little harder for them to catch up with their rivals. One of the symptoms of this backwardness is an extravagant increase in population."

"The unadapted peoples are living in archaic agricultural civilizations the adapted peoples in civilizations of the industrial type. Individually, men are neither less intelligent nor less good and certainly not less happy in a so-called "backward" society than in our own, so long at least, as no one has tampered with the centuries-old empirical balance that has allowed man to gain a living in that society.

"Each of the two civilizations has its own individual type of birth rate, but—as soon as the two societies come into contact, they tend to have the same type of death rate. The result, for the archaic communities, is a sudden and extravagant increase in their population.

"The two civilizations not only have different types of birth rates. In the economic field, they display fundamentally different types of productivity.

"In archaic societies, . . . resources remain more or less stationary. With good luck they may increase a little, but they tend to diminish once they have reached a ceiling. The inevitable result of this simultaneous growth of population and diminution of resources is a constant, tragic, progressive, and inexorable fall in the standard of living.

"In industrial civilizations, the increase of wealth is swift and, as far as one can judge, without any limit, while the figure of the population changes little, sometimes not enough. The result is the exact opposite of the trend in archaic societies, and we see a constant and substantial rise in the general conditions of the population's existence.

"When the mean individual income in each sector is worked out it will be seen that the standard of living is falling faster in the so-called underdeveloped countries than it is rising in modern ones. Now, as soon as the economy of an archaic country begins to collapse, a parasitic class comes into being which corners an increasing share of the national income. Their digestion of these only whets the parasites' appetite for the absorption of the other resources of the country. About one-fourth of the world's population is growing steadily richer while three-fourths is becoming pauperized."

Pauperization of these three-fourths is the crime of the 20th Century.

This brief book should be read by everyone who can read.

THOMAS H. LANGLOIS